Workshop on
Philosophy &
Engineering

WPE2008

The Royal Academy of Engineering
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November 10th-12th 2008

Supported by the Royal Academy of Engineering, Illinois Foundry for Innovation in Engineering Education (iFoundry), the British Academy, ASEE Ethics Division, the International Network for Engineering Studies, and the Society for Philosophy & Technology

Co-Chairs: David E. Goldberg and Natasha McCarthy
Deme Chairs: Igor Aleksander, W Richard Bowen, Joseph C. Pitt, Caroline Whitbeck

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Workshop Schedule

Monday 10 November 2008

All Plenary sessions take place in F4, the main lecture room

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09.45 – 10.45 **Billy V. Koen:** ***Toward a Philosophy of Engineering: An Engineer's Perspective***

10. 45 – 11.15 Coffee break

11. 15 – 12.45 **Parallel session – submitted papers**

A. F1 Mikko Martela Esa Saarinen, Raimo P. Hämäläinen, Mikko Martela and Jukka Luoma: *Systems Intelligence Thinking as Engineering Philosophy*
David Blockley: *Integrating Hard and Soft Systems*
Maarten Frannsen and Bjørn Jespersen: *From Nutcracking to Assisted Driving: Stratified Instrumental Systems and the Modelling of Complexity*

B. F4 Ton Monasso: *Value-sensitive design methodology for information systems*
Ibo van de Poel: *Conflicting values in engineering design and satisficing*
Rose Sturm and Albrecht Fritzsche: *The dynamics of practical wisdom in IT-professions*

C. G1 Ed Harris: *Engineering Ethics: From Preventative Ethics to Aspirational Ethics*
Bocong Li: *The Structure and Bonds of Engineering Communities*
Priyan Dias: *The Engineer's Identity Crisis:Homo Faber vs. Homo Sapiens*

12.45 – 14.00 Lunch

14. 00 – 15.30 **Tutorials**

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F4: Peter Kroes and Maarten Franssen – *Sociotechnical Systems*
G1: Mark Somerville and Sarah Bell – *Reflections on Engineering Education*

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16.00 – 17.30 **Jerome Ravetz:** ***Maintenance as morality***

17.30 – 19.30 Reception at the Royal Society

Tuesday 11 November 2008

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11.15 – 12.45 **Parallel session**

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Michael Pryce: *Descartes and Locke at the Drawing Board: Philosophies of Engineering Design*
Bruce Vojak, Raymond L. Price, Abbie Griffin: *A Polanyian Perspective of Breakthrough Engineering Innovation*

E. F4 Aaron Sloman: *Virtual Machines in Philosophy, Engineering and Biology*
Russ Abbott: *Constructive Emergence: A Computer Scientist Looks at Philosophy*
Enrong Pan: *A Philosophical Model of the Relationship between Structure and Function in Engineering Design*

F. G1 Rune Nydal: *Normative cross-over terms - The ethos of an ultrasound screening programme*
Dingmar van Eck: *On Engineering Meanings of Functional Decomposition*
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12.45 – 14.00 Lunch

14.00 – 15.30 **Tutorials**

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F4. Karen Tonso – *Feminist issues in engineering*
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Viola Schiaffonati: *From Philosophy of Science to Philosophy of Engineering: The Case of AI*
John R. Allen: *Whither Software Engineering*
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H. F4 Heinz C. Luegenbiehl: *Dual Responsibilities: Balancing Employee and Engineering Considerations in Engineers' Decision-Making*
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Hans Radder: *Have we just moved into the age of technoscience?*
Diane Michelfelder: *Artes Liberales and Ethics for Engineers*

I. G1 W Richard Bowen*: Promoting a Culture of Peace within Engineering – Engineering for the Promotion of a Culture of Peace*
Darryl Farber: *Philosophies of Sustainability and Engineering the Nuclear Fuel Cycle - Scenarios for the Future of Nuclear Power*
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Wednesday 12 November 2008

9.00- 9.30 Tea and coffee

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09.45 – 10.45 **Carl Mitcham: *The Philosophical Weakness of Engineering as a Profession***

10.45 – 11.15 Coffee Break

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Peter Simons: *Varieties of Parthood: Ontology learns from Engineering*
Joel Moses: *Toward an Ontology for Systems-related Terms in Engineering and Computer Science*

K. F4 John Monk: *Emotion, Engineering and Ethics*
Kieron O'Hara: *The Technology of Collective Memory and the Normativity of Truth*
Taft Broome: *Social Heuristics in Engineering*

L. G1 Sarah Bell, Joseph Hillier and Andrew Chilvers: *Beyond the modern profession: rethinking engineering and sustainability*
Nicholas Mousilides: *Reflections on Integrating Engineering Education within the Elementary School Curriculum*
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14.00 – 15.30 **Parallel Session – submitted papers**

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Mo Abolkheir: *The Five Epistemic Phases of Technological Inventions*
Caroline Whitbeck*: Post-Enlightenment Philosophical Ethics and its Implications for Practical (and Professional) Ethics*

N. F4 Antonio Dias de Figueiredo: *Toward an Epistemology of Engineering*
Oliver Parodi: *Hydraulic Engineering Reflected in the Humanities*
Cao Nanyan and Su Junbin: *Textual Research on Professional Awareness of Ethics in up-to-date Constitutions of Chinese (mainland) Engineering Public Organizations*

O. G1 Susanna Nascimento and Alexandre Pólvora: *Hitches & Prospects: Outlining Portuguese Encounters of Philosophy, Sociology and Anthropology with Engineering*
Fotini Tsaglioti*: 'Steamy Encounters': Bodies & Minds between Explosions & Automation*
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15.30 – 16.30 **Wrap-up session**

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Invited Speakers' Abstracts

***Billy V. Koen** (University of Texas at Austin), author of* Discussion of the Method: Conducting the Engineer's Approach to Problem Solving.

Toward a Philosophy of Engineering: An Engineer's Perspective

Abstract: If there is to be a Philosophy of Engineering, at the very least there must be an understanding of what the human activity we call engineering is. It is hard to see how a philosophy of anything could be developed when there is little understanding of what that anything is. PartI reprises an increasingly popular definition of engineering: "The engineering method (often called design) is the use of heuristics to cause the best change in an uncertain situation within the available resources." Since this conference concerns engineering ethics as one branch of a Philosophy of Engineering, it also shows how ethics enters engineering practice theoretically and how this differs from the classical view of Plato. Likewise, an effort to establish a Philosophy of Engineering must be based on an understanding of what the human activity we call philosophy is. How can an individual philosophize without knowing what to philosophize means? As a direct consequence of Part I and a series of demonstrations of Godels proof, the EPR experiment, multiple logic systems, and so forth, a new definition of philosophy that is consistent with engineering emerges as "Philosophy is the study of the heuristic by heuristics. Part II examines this view of philosophy as it applies to a Philosophy of Engineering.

Jerry Ravetz (Consultant & James Martin Institute, Oxford University), author of *Scientific Knowledge and Its Social Problems* and *A No-Nonsense Guide to Science.*

Maintenance as Morality

Abstract: Maintenance is a low-status activity, done by technical rather than professional staff, employing a different sort of knowledge, and not usually enjoying the attention of philosophers. Yet maintenance is a key indicator of the morality that defines a socio-technical system. Because it is easily deferred and neglected, it will be the first budget item to go; and then when the effects of poor maintenance appear, it is too late. When maintenance is downgraded, could we say that the socio-technical system gets the failures it deserves? Under what circumstances does maintenance receive proper respect?

Deborah G. Johnson (University of Virginia), author of *Computer Ethics* and *Ethical Issues in Engineering.*

An STS-Informed Account of Engineering Ethics

Abstract: In the last several decades the field of Science and Technology Studies has flourished and developed a rich set of concepts and theories for understanding the relationships among science, technology, and society. Building on an earlier paper on the topic, this presentation will press further in drawing out the implications of STS accounts for our understanding of the social responsibilities and accountability of engineers.

Carl A. Mitcham (Colorado School of Mines), author of *Thinking through Technology: The Path between Engineering and Technology.*

The Philosophical Weakness of Engineering as a Profession

Abstract: One can distinguish between two kinds of professions. Strong professions, such as medicine and law, rest on the formulations of ideal goals that are also well embedded in the professional curriculum and practice. Weak professions, such as military and business, either lack such ideal goals or only weakly include the relevant specialized knowledge in a professional curriculum and practice. The (somewhat intentionally provocative) argument here will be that engineering had more in common with weak than with strong professions

Systems Intelligence Thinking as Engineering Philosophy

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Systems, Engineering, Philosophy, Intelligence, Emergence,

1. SYSTEMS INTELLIGENCE

As human beings we are always engaged and embedded in a context and in the process of becoming. We have to operate inside complex interconnected wholes that involve feedback mechanisms and emergence. The key word is relationality. Remarkably, human beings have capabilities to make use of such complex and emergent wholes in their environments even as they unfold. Hämäläinen and Saarinen have suggested that it is useful to conceptualize this set of capabilities as *systems intelligence.*

Systems intelligence was introduced in 2004 by Raimo P. Hämäläinen, an engineering professor, and Esa Saarinen, a philosopher, in an article entitled "Systems Intelligence: connecting engineering thinking with human sensitivities" [1]. The basic idea was to establish an integrated framework to account for impact-seeking and solution-focused action in the process of its emergence, something the authors considered to be essential to engineering thinking.

Engineering thinking, conceived in terms of systems intelligence, does not reduce to intelligence *of* systems or to intelligence about any other from-outside identifiable objects. This is more radical than might seem. Much of engineering thinking appears to be about systems-as-identifiable-objects, and it is tempting to see engineering brilliance to be about the handling, regulating and controlling of such systems. There seems to be an objectival fundament built into the very essence of engineering thinking, one that depicts the engineer to be an expert of envisioning and implementing control over thing-like complex system-objects.

The systems intelligence perspective of Hämäläinen and Saarinen shows how inadequate such a perspective of engineering thinking is. To be sure, engineering thinking involves rational control over making object-like systems work, but at the same time also much more than that. In engineering thinking, the systems intelligence perspective emphasizes, it is critical to recognize the subjectival and sensitivity-based dimensions of the human endowment as an integral part of what makes engineering thinking *itself* work. Engineering thinking, contrary to what might be thought *prima facie*, does not reduce to objectivism, narrow rationalism or controllism over object-like systems.

The systems intelligence perspective approaches the human condition as an ongoing engagement with holistic systems. Holistic systems are "complex wholes which have properties that emerge from the functioning of parts many features of which are due to their connectivity, modes of interaction and mutual interplay" [2]. As Hämäläinen and Saarinen emphasize, the human understanding of the whole and its effects on us is always partial and biased, and yet we have to act [3]. As Hämäläinen and Saarinen put it, "instead of getting taken aback because of uncertainty, instead of becoming mesmerized when facing the complexities of a system, the call of Systems Intelligence is a soft but confident battle-cry for action." [4] Systems intelligence emerges from the three fundamentals of the human condition, i.e. (i) the contextuality of the human engagament (ii) the complexity of any context, and (iii) the necessity to act. It is the subject's ability to engage fruitfully and successfully with the complex and holistic systems of her environment that the systems intelligence perspective wants to highlight. As Hämäläinen and Saarinen put it, "This fundamental capacity is action-oriented and adaptive, holistic, contextual and relational, and links the subject to her environment as an ongoing course of progression. It amounts to an ability to connect with the complex interconnected feedback mechanisms and pattern structures of the environment from the point of view of *what works.*" [2].

As pointed out repeatedly by Hämäläinen and Saarinen, a key feature of systems intelligence is that the subject need not be in a position to describe or conceptualize the system in which she is acting intelligently. For an adequate understanding of engineering thinking, this point is critically important to appreciate. It runs counter to what one might assume on the basis of the strong rationalism and objectivism of much of engineering thinking.

On the face of it, engineering thinking is about objectivity, rationality and about being explicit. To be sure, all those characteristics might hold true of the outcomes that result from engineering thinking. Yet engineering thinking itself is too much engaged in *action in the present moment* and in the *commitment to drive improvement*, to hold back its creative forces because of the lack of objectivity, rationality or explicitness. After all, for the engineer, the primary focus is to make something work now, as opposed to providing a rational, objective representation of something that worked upon some previous time. An engineering science might benefit from hindsight but engineering thinking itself looks primarily to the future. It seeks the next stage whereupon something gets improved.

Again this is in line with how things ought to be from the point of view of systems intelligence. Systems intelligence, as Hämäläinen and Saarinen emphasize, is not intelligence with respect to some predetermined and fixed, ontologically prior systems only. What the relevant system is, is a matter of choice and interpretation. In this sense "the systems approach begins with philosophy", as C. West Churchman once put it [5]. And engineering thinking begins with systems intelligence.

When comparing systems intelligence with systems thinking, Hämäläinen and Saarinen have suggested that systems thinking easily falls victim to what could be called *the trap of modelling* resulting in a description focus rather than action focus [6]. The systems intelligence perspective stresses the latter. It acknowledges the immense usefulness of the objectifying apparatus of systems thinking while at the same time taking seriously the dimension of human sensitivity.

Here it is particularly important to observe that engineering thinking, as a drive towards solutions and improvements, owes much of its success to the right kind of management of ignorance and uncertainty in the context at hand. Likewise, acknowledging the nature of productive action *in the presence of uncertainty* is the key to appreciating chief insights of systems intelligence. If much of the time we cannot know what the systems are and still manage to live successfully in the middle of them, surely this is an important capability!

One fundamental nature of the human life is that it involves engagement. Indeed, the call for *living successfully with emergent and interconnected wholes* is there even when one cannot identify objectively the wholes in question. “In a paradigmatic case, the systems that humans are intelligent in and with, are not ‘thing-like’. “ “Some of the relevant systems are out there to be depicted, modelled, analysed and represented. Some other are not.” “Systems intelligence reaches out to a productive interplay with systems irrespective of the epistemic status of those systems.” [4]

This highlights an often overlooked feature of engineering thinking. While celebrated for its control of systems and abilities to produce ingenious end-systems, engineering thinking at its authentic best is something other than its end-products. Engineering thinking is fundamentally an orientation to one’s enviroment from the point of view of improvement, rationality and action. The question of the availability of models and representations is only secondary. Engineering thinking, in other words, is systems intelligence. It combines the sensitive, passionate, instinctual, pre-rational and subjective aspects of the human endowment with cognitive, rational and objectivity-related epistemology in the service of improvement with the means that are available.

2. PHILOSOPHY OF ENGINEERING VS: ENGINEERING PHILOSOPHY

There is an important distinction to be drawn between philosophy of engineering and engineering philosophy. The former looks at engineering from a philosopher’s perspective [7]. Standing outside the actual practice, it reflects and contemplates on engineering, conceptualizes important aspects of it and calls into question some background premises previously unnoticed inside the practice. It operates in the dimension of the conceptual, and its project is to make something that is implicit to become explicit. It can shed light on many significant issues the practitioners themselves might have overlooked. Philosophy of engineering is essentially what results when the methodologies and concepts of philosophy as an academic discipline are applied to the field of engineering.

Engineering philosophy and engineering thinking, on the other hand, are something quite different. By engineering philosophy we refer to the mindset and general orientation of an agent that seeks out an improvement in some identified part of her environment with a conviction that an improvement-generating solution to a problem at hand does exist, as well as possibility of working out the improved state of affairs. An engineering philosophy might not be explicit or articulated. It might involve instincts, feelings and aspirations and might rely heavily on human sensibilities as well as on objective knowledge. It might not impress an academic philosopher as being “philosophy” in the first place. It is out there to change the world for the better, and everything else is secondary, including the legitimacy of the improvement-attempt in question.

As a mindset of systematic impact-seeking action, engineering philosophy reigns far beyond the field of pure engineering. Indeed it is useful to think engineering as comprising a distinct and fundamental way of approaching the world. Engineering philosophy means looking at the world with the conviction that rationality-based and incremental steps can be taken in order to produce improvement. Essentially an optimistic philosophy, it amounts to looking how to cause, using the apt words of Billy V. Koen, “the best change in a poorly understood situation within the available resources” [8].

The distinction between explanatory sciences and design sciences, as articulated by Herbert Simon [9], is useful here. Explanatory sciences are occupied with accurately describing the world. Most sciences as well as much of traditional philosophy fall within this category. For design sciences, accurate description is only one means to something truly important. The aim of design sciences is to produce a desirable change. Applicability of a theory, model or artifact is the measure of its usefulness, not its accuracy. It is a “science of making things better.” Engineering is perhaps one of the purest forms of design sciences when understood as Koen suggests as an occupation to generate the best change in a poorly understood situation within he available resources. Engineers are not concerned with knowledge per se, but with a sort of *design knowledge* [10], knowledge through which a desirable change in the human environment can be made [11].

As a leading representative of Simon’s design sciences an engineer, however, is also an artist. The “making of the better” might not follow any scientifically respectable methodology. The way an engineer generates a solution might be highly idiosyncratic. It might only apply to the context at hand and for reasons that cannot be identified. While at first sight perhaps surprising, this is how things should be, according to systems intelligence thinking. As pointed out by Hämäläinen and Saarinen repeatedly, an agent can maneuver intelligently and successfully in systems she cannot comprehend scientifically. Once again, the point is success in action rather than in the methodologically correct representation or scientific legitimacy of that action.

The history of engineering shows that science is a tremendous instrument where it can be applied. Instrumentality is the key – the core value for engineer thinking. This leads to the use of science as an instrument. But it is a serious mistake to believe that this exhausts the available resources of an engineer who wants to *make things work.*

There is a relativistic dimension to engineering thinking in the engineer’s mindset. Might not an improvement upon a system serve the cause of the bad and the interest of the evil? Might not the focus be upon a system that should not be improved? Absolutely! A pressing theme for philosophy of engineering is the illumination of some of the value elements involved in the adopted practices and technologies. In engineering thinking, the value of improvement and of instrumentality is one that is relative to a given context and a particular set of parameters that define what the relevant improvement is. Engineering thinking does not assume absolutely given criteria for improvement or what counts as better.

Again this is in line with how things ought to be from the point of view of systems intelligence. Systems intelligence, as Hämäläinen and Saarinen emphasize, is not intelligence with respect to some predetermined and fixed, ontologically prior systems only. What the relevant system is, is a matter of choice and interpretation.

3. APPLYING SYSTEMS INTELLIGENCE

The systems intelligence perspective has been applied to a number of themes across a number of disciplines. The following examples hopefully illustrate the usefulness of the concept and how natural it is as a framework of explicating engineering philosophy.

In discussing the industrial future of Finland, J. T. Bergqvist, the former member of the executive board of Nokia, identifies *superproductivity* as a key component in the new strategic paradigm for the country's industrial endeavours [12]. Superproductivity occurs whenever a non-linear productivity gain is reached through an innovation – whether this innovation is related to business models or value chains (e.g. Ikea), products (e.g. machineroom-less elevator of Kone) or to the business process (e.g. Wal-Mart). Bergqvist argues that a company works as a system constituted of people whose mutual interaction has a greatly amplified effect on energy creation and innovation capability. Therefore creating the right kind of atmosphere is the key prerequisite for superproductivity. This atmosphere is built up in day-to-day social encounters through often trivial looking interaction patterns, like listening and giving space to other people's opinions, begging your pardon after having hurt somebody, encouraging people or celebrating even small advances.

In his essay [13], Martin Westerlund gives an articulation of the theory of constraints of Eliyahu Goldratt, an "intuitive yet highly capable tool to address shortcomings in efficiency" in organizations and other human systems. According to the theory of constraints every system is equipped with at least one constraint and by identifying these constraints and by focusing our efforts of improvement on them the system can be elevated to new level of performance [14]. Westerlund argues that the perspective of systems intelligence with its holistic and change-seeking focus could complement theory of constraints by helping to identify and utilize the *trigger points* of a system, trigger point being "the constraint or catalyst that acts as the most crucial inhibitor or most potential activator, respectively, of enhancement". Systems intelligent person "automatically perceives a system as a field of opportunities – that is, an environment with certain trigger points the leverage potential of which he seeks to unleash".

Environmental issues is the area where engineering thinking and systems intelligence are most urgently needed. Environmentally sustainable policies and technological challenges are typically holistic and complex, and characterized by the imperative to act. Change can be done in a constructive mode by employing systems intelligence. Environmental issues typically embed conflicting criteria and interests. It is essential and systems intelligent to shift the focus from "reactive and conflict driven thinking" into "self encouraged co-operation and positive trust" through defining a common goal and innovative ways to reach it [15]. On a more general level systems intelligent approach to environmental leadership calls for a "co-operative, inclusive and systemic approach" [16]. It acknowledges the fact that most large-scale systems are extremely resilient to change attempts which do not take into account the forces and interconnections within the system. Therefore these implicitly confrontational and dualistic change attempts from the outside usually fail no matter how much pressure or even brute force is used. Instead, "successful change takes place – and successful leaders operate – from within the prevailing systems, utilizing the values, dynamics and feedback connections of the systems to achieve sometimes gradual, sometimes rapid changes with relatively little effort." In this spirit, systems intelligence and engineering thinking join forces in the vital and noble aim of creating sustainable environmental leadership.

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Integrating Hard and Soft Systems

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1. Keywords

Philosophy, Engineering, systems thinking, hard and soft systems, decision, quality, dependability, process, risk

2. ENGINEERING IS AN ART AND A SCIENCE

Many years ago I was listening to a well know jazz critic interviewing Louis Armstrong on the radio. After a long erudite discussion of the contrapuntal complexities of his trumpet playing the critic asked 'Louis how do you do it?' The reply delivered in typical rasping style was, 'Man I just blows.'

Why is this relevant to engineering? Because, like Louis, much of what practitioners actually do is as a result of experience - they learn from doing the job. However if Louis had blasted a wrong note then his career would have suffered - but little else. The consequences of engineers or indeed many professional practitioners such as medics, making a wrong decision can be loss of life.

Music is obviously an art form. Classic definitions of art often refer to two basic elements – knowledge and production. Art is knowledge of the rules for making things - but also the capacity for making something – a power of the practical intellect. So extemporizing musical patterns is a form of practical art as is building a bridge. Art is about making – it is a skilled way of living. Modern definitions of art tend to refer to an exploration and expansion of perceptual awareness of the world around us.

Engineering is often said to be an art and a science [1]. This is what makes it philosophically interesting. It concerns knowledgeable decision making in order to accomplish a human goal such as to build a bridge. But how do we know the truth of what we know?

I will use the only 'common sense' interpretation of truth which is credible to most practitioners i.e. that a statement is true if it corresponds to the facts. Philosophically this definition is unfortunate as it leads to an infinite regress and we have to rely on a meta-system to establish the truth of the facts. The view that science gives us Truth (notice the big T) is discredited – yet its legacy lives on. So in practice how do we judge what is true? How dependable is that which we know? These are central philosophical questions which have obvious practical implications for engineers.

Engineers, like all practitioners have a duty of care under the Law of Tort, to act responsibly [1]. But what does that mean? To act responsibly engineers must always do what is reasonable. This means that they must be aware of the latest developments – particularly in science [2]. They must know what should be reasonably known. Ultimately the only test within the rule of law that stands credibility is that the peer group decides what is or what is not reasonable.

3. ENGINEERS NEED DEPENDABLE INFORMATION

I will use Truth (with a big T) to capture information that is true in all contexts. Unfortunately this is only available to us through faith. We can believe in Truth (usually through religion) but science is only true. Here I use a small t to emphasise that science corresponds to the facts in certain contexts that may or may not be well understood. Newton's Laws enable us to do incredible things but there are situations where even they breakdown. Engineering is full of situations where information is approximate, vague and incomplete with random variations. 'Rules of thumb' based on long experience often fill the gaps. If these situations are not understood then potentially we can make big mistakes

In order to make (I am using the word in its biggest sense i.e. to conceive, design build, operate and dispose) something engineers must take decisions to solve a long series of many difficult problems. Decisions are based on criteria which express values. Ethics is therefore at the heart of engineering – how do we establish the worth of anything? Decisions lead to actions and then a change in the state of the world. There is always a chance that events will not turn out as planned or expected. Karl Popper rightly pointed out the importance of unintended consequences. Indeed social science, he argued, should be the study of unintended consequences. It follows that to any practitioner decisions are about risk. Engineers have a duty of care to minimize the risk of failure – in other words to try to ensure that things do turn out as desired.

4. TRUTH IS TO KNOWLEDGE AS RISK IS TO ACTION

Just as the nature of truth has been a central question in epistemology so the nature of risk is a central question for philosophers of engineering. I maintain that truth is to knowledge as risk is to action. Following Popper [2] testability is the demarcation between science and non-science. Engineers can and do test much of what they do, but not all. Consequently we have to recognise the inevitable role of experienced judgement in practical decision making.

Engineering has changed markedly over the last decades. Not only do we have new powerful knowledge and computational tools but there are different challenges such as terrorism and climate change. There have been some large scale failures and as a result there is a much greater awareness of the need to deal explicitly with risk in all aspects of life. A key difficulty is how decision makers integrate information from many disparate sources to manage risks [3].

5. ENGINEERING PROJECTS ARE TEAM PERFORMANCES.

In many projects, accountants manage the known financial risks well, the engineers manage the known technological risks well, the safety specialists manage the known health and safety risks well and the quality managers manage the known processes well and so on. However major problems, even in successful companies, seem to arise in the gaps between these specialisms resulting in unknown and unintended complications such as cost and time overruns and consequent quality problems. But even within specialisms a range of techniques may be used to assess different aspects of risk which are difficult to integrate.

Hard systems are physical systems that are commonly said to be 'objective' in that they are supposed to be independent of the observer and hence the same for all of us. Soft systems are, as the name implies, systems which are hard to define – the edges are unclear. Generally soft systems are governed by the behaviour of people which is so complex as to be hard to define. The emphasis in soft systems therefore is not on prediction but rather on managing a process to achieve desired outcomes. Experience has demonstrated that highly interconnected hard and soft systems can be vulnerable to small damage. We need to understand this better.

6. THE KEY IS TO THINK PROCESS

Processes are the way things behave in hard systems and what people do in soft systems. All designed hard systems have a function which is a role in a process. For example a beam in a structure has the function of carrying the loads from the floor slab. A dam has the function of holding back the reservoir water. The steel and concrete of which the beam and the dam is made does not 'know' it has that function – it has no intentionality. The function is ascribed to a hard system by us, the people who own it, conceive it, design it, build it and use it. We are also the ones who decide when the hard system has failed and we decide the criteria of failure. Clearly some functions are obvious - others are less clear and unintended. For example a bridge designed to carry road traffic was almost certainly not designed to be used as a shelter by homeless people. In one case the cost of repair, to concrete damaged by the fires lit by homeless people to keep warm under a bridge, was substantial.

A measure of the quality of a hard system is its fitness for purpose as defined within a soft system. The purpose of a soft system is an ethical question. A measure of the quality of a soft system is its fitness for purpose in a hierarchy of human needs at the apex of which is human flourishing.

7. WHAT DO WE TAKE FROM ALL THIS?

Engineering is practical problem solving that requires risky decisions and actions.

1. Knowledge is always incomplete – Truth in all contexts is unavailable.
2. Decisions are based on evidence. Evidence has varying ‘pedigree’ varying from the highly testable truth content of Newton’s Laws to experienced opinions about the future variations in financial interest rates. We have to develop a better understanding of the dependability of evidence, how to assess it, how to capture the context in which it is dependable and importantly how to capture when it should not be used.
3. Truth is to knowledge as risk is to action.
4. Ethics has a central role because decisions are made using criteria. These criteria are expressions of worth i.e. values.
5. All designed hard system processes are embedded in one or more soft system processes.
6. We have to understand risk better. This is a central task for a philosophy of engineering.
7. Highly interconnected systems can be vulnerable to small damage. We need to understand this better.
8. When systems fail it is not always the fault of an individual. Systems failures may be complex. These issues must be addressed in a dialogue with the general public so they understand better what is or is not a reasonable expectation of decision makers from politicians to engineers. This last point is of increasing importance in debates about climate change

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From Nutcracking To Assisted Driving: Stratified Instrumental Systems and the Modelling of Complexity

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Traditional engineering design fails to adequately incorporate into its modelling practice the *hybridity* and *stratification* of complexes that involve not only technical *artefacts* but also individual *people* playing different roles, as well as social *institutions* such as laws, norms, and regulations. In this talk we propose a novel way of conceptualising this complexity.

We introduce the notion of *instrumental system* as the central entity of our systems analysis. In general, an instrumental system is a structured complex whose constituents are intentionally arranged in such a way as to transform a particular kind of input into a particular kind of output in a particular way.
An instrumental system is defined to exhibit these three slots in this particular order:

$$\textit{Instrumental system} =_{\mathrm{df}} \langle \textit{Input}, \textit{Instrument}, \textit{User} \rangle.$$

We are pretending that ordered *n*-tuples are capable of representing structure. An example of a simple instrumental system would be a nut-cracking system, whose parts are slots for a nut-cracking device, a nut, and an agent. A nut-cracking system is not a mere aggregate of elements, but one hybrid unit straddling two or more ontological spheres.

The correct execution of a well-designed nut-cracking procedure will take the system, if functioning as designed, from one state to another (from being idle to having cracked a nut), and similarly for the agent (from having a whole nut to having a cracked nut). The agent's motive for executing the procedure is to obtain the second state, and instrumental systems must serve to bring about such controlled manipulations of their input.
The intuitive way to approach the question of interaction between user and instrument is to ask what 'button' the user needs to 'push' in the instrument to get it to work. Sometimes there is literally a button to push, as when fetching yourself a cup of coffee from a coffee-vending machine. Oftentimes the 'button' is a figurative one. The 'button to push' in the case of a nut-cracking system whose instrument slot is filled by a nutcracker (and not a makeshift nut-cracking instrument like a stone) is its handle. The handle was designed to be grabbed and held by a human hand and is the point of entry of the interface between artefact and user.
A nut-cracking system is a *first-order* system, since each of its three slots is simple (non-complex). A *higher-order* instrumental system has at least one complex slot, and any or all of its slots may be complex. That a slot is complex means that it is itself systemic, by being a structure boasting at least two parts: $\langle a_1, a_2, \ldots \rangle$. We identify *stratified* systems with higher-order systems. An example of a stratified system would be one whose instrument slot was complex, as in

$$\textit{Assisted-driving system} =_{\mathrm{df}} \langle \textit{Passengers and/or goods}, \langle \textit{Vehicle}, \textit{Driver} \rangle, \textit{Client} \rangle.$$

The client does not himself drive the vehicle serving as a cab, nor is the driver the user of an assisted-driving system. The 'button' that the client 'pushes' in order to set this system in motion is this time an abstract one: he uses (rudimentary) language to communicate his destination to the driver. Notice that the individual filling the client slot may, but need not, be the individual filling the passenger slot; for instance, a concert organizer may instruct the stretch car driver to pick an opera diva up at the airport and drive her to the venue while not riding along.

The above system counts as a second-order system, because at least one element is a first-order system (here, the instrument slot). So a first-order system is one all of whose a_i in $\langle a_1, a_2, \ldots \rangle$ are non-systems (i.e., primitive from the point of view of an instrumental system). Conversely, when the systemic part of the highest order of an instrumental system is of order *n*, the entire system is of order *n*+1.

Our talk offers a fairly straightforward and intuitive categorization of the complexity of various instrumental systems. This categorization underpins a taxonomy of instrumental systems. The talk provides an ample supply of examples of different kinds of instrumental system explicated by means of real-life examples.

Value-sensitive design methodology for information systems

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Keywords

Value-sensitive design, social informatics, socio-technical system, institutional economics, bias.

1. INTRODUCTION

Value-sensitive design is a growing discipline, but methodologically, tools to identify values and design for them are hardly available:

> *"The practical challenge conscientious designers face integrating values into diverse design projects, is due, in large part, to the sparseness of methodologies and, relatedly, the newness of the endeavor." [1]*

Before designers can work with the notions of value-sensitive design (VSD), and include normative aspects already in the early phases of a product or system life cycle, an extension of the methodological tools to analyse and design for values is needed.

This paper tries to contribute to the methodology of designing for values with regard to socio-technical systems around an information system by discussing the use of a conceptual framework borrowed from the discipline of heterodox economics. VSD is often associated with information systems, although it is not necessarily confined to that strand of technology. More specifically, we focus on the translation of values (intentions) into consequences (of choices) for systems that support information exchange in the public domain. The framework has been applied in a research project where we conducted an extensive literature study aimed at thoroughly analysing a case around policy considerations regarding information sharing on children, complemented with thirteen expert interviews. The group of experts was heterogeneous and consisted primarily of people fulfilling an executive responsibility, either as project leader, policymaker or practitioner.

Developing a framework has both theoretical and practical relevance. 'Design' is on crossroads: a design process leads to the creation of artefacts, but it can be inspired by and based upon theory. We regard VSD theory to be aimed at prescription, as design is creational by definition. We suggest to (initially) limit the use of the framework to the exchange of personal information in the public domain, as our framework is inspired by a case study aligned with this definition. Also, we think that this strand of systems have a special need to consider the institutional aspects beyond the technical, as many actors are involved and multiple, often contradictory values should be taken into account. At the core of our analysis, we use a framework that is explicitly developed for socio-technical systems, characterised by unruly technology, the involvement of multiple parties, both public and private, the existence of market forces and government regulation [2]. The market forces are not that relevant in our case, but the other characteristics match the definition of the exchange of sensitive information in the public domain.

We consider it inevitable to analyse the ways in which values manifest themselves, before we can suggest deliberate design considerations. Therefore, we will discuss the exploratory/descriptive and prescriptive part separately. To conclude, we will reflect upon the pros and cons of the methodology presented.

2. LITERATURE

VSD recognises that technology and institutions are interrelated. This insight runs parallel with thinking in other disciplines [e.g. 2,3,4-6]. Technology and institutions are both value-laden [7]. Compelling examples are biases in computer systems [8] and classification biases [9].

VSD is promising, but its methodology is not mature yet. Several contributions have been made, among which are values in design [1] – which draws upon the triad discovery, translation and verification – and critical technical practice, a methodology aimed at bridging the world of cultural reflection and design, which may also be applied to values in technology [10]. Some people consider value-sensitive design as a specific methodology, because Friedman and others – who coined the term value-sensitive design – have also made methodological contributions (e.g. Friedman, Kahn Jr. & Borning [11], where they distinguish conceptual, technical and empirical investigations. Nevertheless, we observe that value-sensitive design is conventionally referred to not as a methodology, but merely as a generic approach, a goal. Hence, we use value-sensitive design as a generic term and distinguish several methodological contributions in it. Earlier contributions in the field are useful, but have not systematically combined institutions ánd technology in their analysis. Moreover, they generally lack rigour and, as such, can structure an analysis, but do not provide much guidance on its contents. We would like to add a methodology aimed at providing more of this guidance. As research proceeds, we expect the VSD field to be able to validate, compare, recombine and improve different methodologies. At this moment in time, the number of case studies and degree of detail of the methodologies does not allow for systematic comparison.

3. IDENTIFICATION OF VALUES

Our analytical framework is borrowed from Groenewegen [12], who extended Williamson's framework from the field of institutional economics [13] with a technology element. The visual representation is given in Figure 1. Four elements deal with institutions and are based upon Williamson's framework. Each of them operates at a different level of analysis. The upper level comprises informal institutions and is hardest to change, the lowest one deals with the interactions between actors and can be changed more easily. Depending on the time scale and the resources of actors, elements could be considered either as constraints or as instruments for a particular actor.

All relationships between the original four elements are bidirectional. Informal institutions shape formal institutions, as formal institutions shape institutional arrangements and so on. The other way around, behaviour can also induce a change in institutional arrangements, the arrangements may lead to new or modified formal institutions etcetera. Next to these elements, Groenewegen introduced technology.

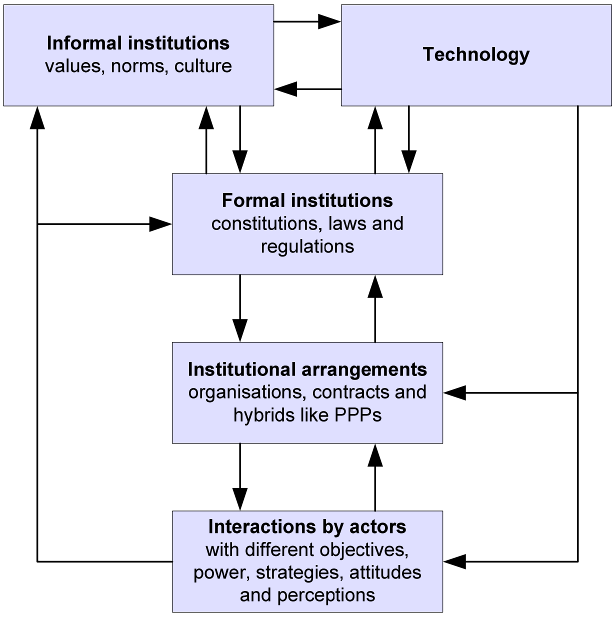

Figure 1. Institutional framework extended with technology.

4. CASE STUDY

We will apply Groenewegen's framework to a single case study: the Dutch national risk signalling system for children with psychosocial problems. We will first discuss the problem domain, and then consequently apply the five elements of the framework to identify biases and other value consequences. The recognition of children with psychosocial problems can be difficult. Many of these youngsters are known by some organisation, such as schools, police, youth care or sports clubs as having a problem. However, the dispersed information is often never combined, so that the informational puzzle around a child is incomplete. Not every professional action requires that all information available elsewhere is aggregated, but combining data pieces may contribute to a better diagnosis or a better intervention. Sometimes, the combination of different concerns leads to an intervention that would not have been taken in the absence of complete information. More certainty by exchanging information across organisations and individuals, hence sharpening the picture of the situation and starting or aligning interventions with the diagnosis, may ultimately contribute to the child's psychosocial health. On the other hand, this very same exchange of information can be problematic because of factors such as informational privacy risks, semantic errors and biases in decision-making.

Based on this case, we have used Groenewegen's framework to identify important decisions and constraints in Figure 2.

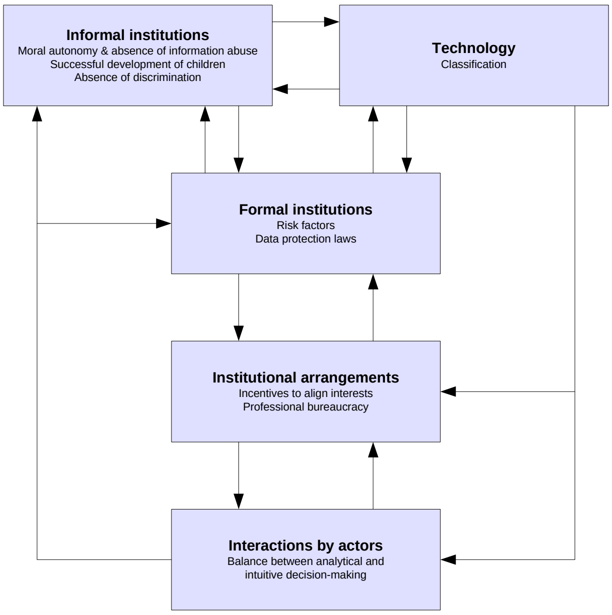

Figure 2. The framework applied.

5. DESIGN FOR VALUES

After the identification of the main elements of an institutional and technical design that impact upon our values, we can use this as a starting point to design with values in mind. We distinguish three ways to do this. First, one can remove or compensate identified and unwanted biases. Think of training programmes for staff working with probabilistic risk factors. Second, one can introduce (positive) discrimination where desired. An example is a systematic focus on youth crime, because of its broad social consequences. Third and final, one can adapt formal institutions, technology and institutional arrangements to favour certain interests over others. Here, one can think of organisations dedicated to defend children's interests, where legal aid to parents is less facilitated. In the paper, we come forward with more suggestions in all three areas.

6. DISCUSSION

We conceptualised Groenewegen's framework to distinguish several elements of an institutional and technical design and look for design choices that impact upon our values. After the application of the framework to our case study, several remarks can be made. First, the framework does seem to be helpful in structuring the identification of value-laden choices. It especially helps to consider different analytical levels and to think in a multidisciplinary way, as it is not tight to a particular discipline. However, its use does not go beyond the identification of five categories and the layered thinking with regard to institutions. This makes the framework both thin and lean. Thin, because it does not provide much analytical direction. It does not direct analysis in a rigid way, but is only a tool in design explorations. Lean, because it can easily be adapted to fit different situations.

The suggested framework can be a starting point for thinking about an improvement of VSD design methodology, but it is by no means a final product. Groenewegen's framework can be adapted to better serve our purposes and increase analytical rigour.

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Conflicting values in engineering design and satisficing

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Keywords:
Engineering design, satisficing, value conflict, moral values, moral supererogation, rationality, search rule

1. INTRODUCTION

An important way in which values play a role in engineering design is by being translated into design criteria that are used by engineers to evaluate different options. Examples of such design criteria are safety, sustainability, user friendliness, costs and privacy. Often such design criteria will conflict with each other. That means that usually the design option that is for example the safest will be more costly or less user friendly than some of the other options. So trade-offs between the different design criteria and corresponding values have to be accepted. In formal engineering methods, like multiple criteria design analysis, such tradeoffs are made by trying the find the "best" option. Such strategies are known as maximizing strategies. If the values that are in play are incommensurable, such maximizing might however be impossible. As an alternative, designing engineers might choose a satificing strategy. In this paper, I discuss potential satisficing strategies for dealing with conflicting values in engineering design and investigate under what conditions, if any, such satisficing strategies would be rationally and morally allowable.

2. SATISFICING IN DESIGN

In contrast to a optimizer, a satisficer does not look for the optimal option but first sets an aspiration level with respect to which options are good enough and then selects any option that exceeds this aspiration level [1]. Designers are reported to be satisficers in the sense that they set threshold values for the different design criteria and accept any design exceeding those thresholds [2]. So conceived, satisficing may also be seen as a way of dealing with conflicting values, i.e. by setting thresholds for each value and then selecting any option exceeding those thresholds. Setting threshold values does not only occur in the design process, but also through legislation and through the formulation of technical codes and standards.

Satisficing can also be combined with maximizing. For example, a designer that has to trade off safety and cost considerations in the design of a chemical installation may well choose to make a design that meets the legal requirements with respect to safety and is as cheap as possible. This can be interpreted as satisficing behavior with respect to the value of safety, while maximizing with respect to cost within the safety constraint.

3. IS SATISFICING MORAL?

Philosophically, an important question is whether, and if so when, satisficing is a morally and rationally allowable strategy. If someone satisfies he does not aim for the best, but for an option that is good enough from a certain point of view. Some ethicists have argued that satisficing with respect to moral values might be allowable: we are in many situations not required to do what is morally best, but we should do at least what is morally good enough (see, e.g, [3, 4]). Risking our life to save another person from a burning house might be morally praiseworthy, but that does not mean that it is morally required. This is known as moral supererogation: not everything that is morally praiseworthy is also morally required.

An argument why satisficing is not only allowed but maybe even advisable in the case of moral values might go as follows. Moral values sometimes resist trade-offs due to their incommensurability. One possible explanation for this is that they may often be understood as moral obligations [5], i.e. as the obligation to meet a certain value to a certain minimal amount. So interpreted, moral obligations define thresholds to moral values. It seems plausible that below the threshold, the moral value cannot be traded-off against other values because the moral obligation is more or less absolute; above the threshold, trade-offs may be allowed. If this picture is right, it provides an additional argument for satisficing with respect to moral values, i.e. by setting the threshold so that all moral values are met to the minimal amount defined by moral obligations. This approach then prevents unacceptable trade-offs between moral values or between moral values and other values.

4. IS SATISFING RATIONAL?

Do the above arguments also apply to non-moral values? An important argument for the existence of moral supererogation is that we have other values and reasons besides moral values and reasons and that these may go against what is morally most praiseworthy. The justification is based on the – presumed – existence of broader perspective that includes the moral perspective, for example the perspective of the entire life of a person.

Can satisficing also be justified at the level of the broadest perspective? Michael Slote argues that it can be rationally allowable to forego the best choice even if we know what the best choice is and it is readily available; he calls this 'rational supererogation' [6]. Slote's argument is much contested (e.g. [7-9]). What makes it especially problematic is that he says that it is rationally allowed to choose some lesser option over an available better option while we have no reason to do so. It seems that we either have a reason to choose the lesser option, which makes it after all not the lesser option all things considered, or that we are simply not rationally allowed to choose the lesser option.

The argument against Slote's position suggests that satisficing cannot be rational at the broadest perspective. It can only be rational with respect to a partial perspective; satisficing on such a sublevel can be rational because, seen from a wider perspective, it is the best way to achieve one's overall values or aims.

5. STATIC VERSUS DYNAMIC CONTEXTS

Another relevant issue with respect to the acceptability of satisficing is whether we are considering a static or dynamic context [1, 7]. In static contexts, all options are known, the consequences of the options are known with a certain probability and the options are readily available. Slote tries to argue that satisficing is rationally allowed in a static context. Such an argument is very hard – if not impossible – to make, but what about the rational acceptability of satisficing in a dynamic context? In a dynamic context, we do not know all the options yet, or it requires efforts to investigate the consequences of options or to make options available. In such a context, we are confronted with the question: how much effort should we put in getting to know better the solution space? Efforts may we worthwhile because there is a chance that we come to know a better option than the options we already know. However, there is a limit: in situations in which the solution space is not closed, we can go on endlessly searching for a better solution but at some point the result are no longer worth the efforts. In such a dynamic context, satisficing may be a useful and rationally defensible stopping rule: Look for a better option until you have found an option that meets all threshold values.

6. CONCLUSIONS

What does the above tell us about the acceptability of satisficing in engineering design? First, it suggests that satisficing with respect to moral values – or more specifically morally motivated design criteria – can be allowed due to the phenomenon of moral supererogation. Second, it suggests that satisficing with respect to other values and design criteria can be rationally justified from a broader perspective. In case of the design of a part or a component, this broader context can be the design process of the entire artifact. In case of a design process for an artifact the broader context can be the sociotechnical system in which the artifact is embedded. The broader context can also be the company that wants to make a profit with a certain design or society that aims at sustaining certain values through technology. Third, satisficing can be rational in a dynamic context in which the solution space is not closed. This is typically the case in many engineering design processes. Therefore, satisficing can provide a rationally defensible stopping rule for the search process that engineering design is.

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The dynamics of practical wisdom in IT-professions
Comparative case studies from the automotive industry

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Information technology, professional ethics, *phronesis*, *techné*.

1. PROFESSIONS AND THEIR RELATION TO WORK

From a management point of view, the understanding of a profession is often limited to the procedures and the outcome of the work that is performed. The question how professionals relate themselves to their work usually remains unanswered. In the words of Aristotle, work is approached by its *techné*, the functional concept of what is done. Such an approach ignores what Aristotle calls *phronesis*: the prudence or practical wisdom which makes someone able to act in a good way [1]. Following Greek traditions, Aristotle distinguished different kinds of activity: *poiesis* and *praxis* in the sense of making and doing and work suitable for free men and work suitable for servants. Later philosophers have also emphasized the distinction between theory and practice [2]. One characteristic of these kinds of activity is that they all need *phronesis* in a different way. A professional becomes an expert by knowing how to do his own kind of work well [3]. One possible explanation for the lack of interest in the question how professionals relate to their work would therefore be that the answer is already included in the character of the profession.

2. THE LACK OF TRADITION IN I.T.

Many professions as we see them today have a long history which goes back to the time when the traditional distinctions of different kinds of work were established. The institutions where these professions are trained often show clear traces of this history. In many countries, the variations between schools for arts and schools for sciences, technical colleges and other forms of education still resemble the old distinctions between making and doing, social status, theory and practice [4]. In other words: when a work is identified with a certain profession, a certain relation to the work is already implied. Architects, designers, engineers and craftsmen all relate to the work they do in their own specific way, which has been a given for centuries and therefore goes without saying. In the field of information technology, however, the situation is completely different. Most IT-professions have only emerged a few years ago and a firm historical foundation for them is missing. Even when procedures and outcome of the work to be done are clearly defined, the way how IT-professionals relate to their work can still be very different. In this paper, we study these differences on various examples from the automotive industry.

3. I.T. IN THE AUTOMOTIVE INDUSTRY

The production of a car involves many different activities. The automotive industry can therefore serve as a very good instance to compare how work is performed in different professions. In a typical company in this field of business, Information Technology represents only one department among many others. The automotive industry started to use computers rather early. However, they were originally developed, installed and operated within the business units where they were used. Separate departments for IT were established in the last decades of the twentieth century, usually staffed with people from the business units, scientists, engineers, accountants or mathematicians. After the foundation of separate schools for information technology at universities, technical colleges and other institutions, experts with a specific training have taken over the majority of the jobs. Basic rules and regulations, work standards and quality measures apply equally to all employees of the company. In addition to that, most companies have established standards for software production, project management and system operation according to the general of information technology. From a functional point of view, the IT department therefore does not show any peculiarities in comparison to the other departments.

4. THE OVERLAP PHENOMENON

During the last two decades, outsourcing has been a major trend in the automotive industry. Like practically all the other departments, information technology has been affected by this trend: specific workloads have been shifted to other companies or locations. However, the outsourcing activities in IT have had a different effect in IT than elsewhere. For research and design, manufacturing and logistics, the outsourced workloads usually represent separate modules in the common work process. In IT, the separation is usually incomplete. A typical example is the ordering system at Daimler. The servers on which it is operated are physically located on different places outside of the company. Databases and front-ends run elsewhere. However, experts from Daimler have various ways to access the systems and databases and participate actively in assuring that the system works correctly. Similarly, the programmers and consultants for the development of new functionality may come from other companies and perform the majority of their work in other towns or even countries. But the access of the code is shared and any decision is made together with the experts from different parts of the Daimler organisation. Where other departments divide work into independent transactions, the activities in information technology tend to overlap. Constant communication is necessary to ensure that the different activities fit together.

5. VARIATIONS OF WORK RELATIONS

When all procedures of the participants are clarified, remaining work overlaps indicate a necessity to reassure frequently that there is a common understanding of what good work means for every single participant. Other examples show that this understanding can evolve in different ways, even when the circumstances of the work are quite similar: As a producer of premium cars, Daimler is committed to the highest possible standards of quality in all aspects of work. Although these standards are enforced by a series of control mechanisms and quality measures, different IT projects show that optimal results are achieved in quite different ways. While there are some projects in which programmers, system designers, database experts or other participants get involved actively in brainstorming, testing and problem solving, the same groups of people will share responsibilities in another way in other projects.

6. LEARNING FROM OTHER PROFESSIONS?

The case studies given above indicate that a certain kind of prudence or practical wisdom cannot be expected as a prerequisite in information technology. Some popular business literature tends to approach this issue as a functional problem. However, it seems unlikely that further rules and regulations to change work procedures will have any effect on it, because such efforts cannot address the relation to the work that is performed and the application of these rules and regulations [6].

It is necessary to consider the human actor who performs the work in a different way. Terms like IT-architect or IT-engineer are attempts to relate to other professions who have a clarified understanding how prudence or practical wisdom is involved. Although these attempts are helpful, the complete background on which these professions rely cannot be taken over so easily. The professions in information technology will have to find their own background.

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Engineering Ethics:
From Preventive Ethics to Aspirational Ethics

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Keywords: Philosophy and engineering, preventive ethics, disaster cases, virtue ethics, aspirational ethics.

1. INTRODUCTION

Traditional engineering ethics has consisted for the most part of what I call "preventive ethics." In preventive ethics, the focus is on preventing engineering disasters and professional misconduct. The primary influences on preventive ethics have been the professional codes of conduct, the so-called "disaster cases," such as the *Challenger* accident, and philosophical theories and analysis. Preventive ethics is usually expressed in terms of rules, and these rules often have a negative orientation. Avoiding such actions as taking bribes, having undisclosed conflicts of interests, violating confidentiality when the interests of the public are not threatened, misrepresenting qualifications, practicing outside one's areas of competence, and whistleblowing when it is necessary to protect the public are standard topics in preventive ethics.

Evidence exists that preventive ethics may be influential in minimizing instances of professional misconduct, and I am not in any way suggesting that it should be eliminated from teaching and research in engineering ethics. Nevertheless, I believe that it should be supplemented by another standpoint, which I call "aspirational ethics."

2. ASPIRATIONAL ETHICS

Aspirational ethics has a more positive orientation. I define aspirational ethics in engineering as the body of concepts and activities oriented toward the attainment of professional excellence and the use of professional excellence to promote the good. Thus, the focus of aspirational ethics is on developing professional character. Of late, several writers in engineering ethics have emphasized a more positive approach to engineering ethics, but all of these approaches differ in some way from aspirational ethics. Caroline Whitbeck and others have made use of the concept of "moral exemplars," [1] and Michael Pritchard has developed the concept of "good works." [2] Both of these concepts, however, tend to focus on works of outstanding merit, whereas aspirational ethics is more oriented toward ordinary engineering work. Furthermore, the main concern of aspirational ethics is professional character, not particular activities of engineers. Mike Martin, in *Meaningful Work*, has shown how personal ideals that have their origin in extra-professional considerations can give meaning to professional work.[3] Aspirational ethics, by contrast, is concerned with virtues that have their roots in professional engineering work itself. Aarne Vesilind, in *Peace Engineering*, has come up with the term "peace engineering" to describe many engineering activities that can contribute to human well-being. [4] The focus, however, is on engineering activities, not professional character, and the inspiration for this work seems to be extra-professional values, not professional values.

3. VIRTUES VERSUS RULES

Aspirational ethics does not lend itself to expression in terms of rules, which are more appropriate for preventive ethics. It is best expressed in terms of virtues or excellences, but it is important to keep in mind that the virtues or excellences of interest are functional excellences, which are qualities that enable a person to perform his own particular function well. While the function Aristotle had in mind was one's function as a human being, the function of interest in professional ethics is the more specific one associated with a social role, such as being an engineer. After pointing out some of the salient features of virtues and virtue ethics, we can proceed to a consideration of a virtue ethics for engineers.

4. A VIRTUE ETHICS FOR ENGINEERS

Virtues appropriate for engineers fall into three categories: competencies, sensitivities, and commitments. Professional competencies, which are intellectual virtues, include technical competencies in such fields as the basic sciences and mathematics, engineering science, drafting, computing skills and creativity in design. Competencies also include what engineers are fond of calling "soft" skills, such as writing, proper professional demeanor, and interpersonal skills.

The second category, sensitivities, which are also for the most part intellectual virtues, includes several sub-groups. One sub-group includes awareness of the ways technology can increase risk. Awareness of perils such as "normalizing deviance," of the limitations of engineering models, and of the deficiencies of such techniques as event trees and fault trees are examples. Another sub-group includes sensitivities with respect to interpersonal and organizational issues that can lead to disasters or at least defective technologies: groupthink, microscopic vision, self-deception, uncritical acceptance of authority are just a few examples. Still another sub-group includes awareness of the ways in which technology can affect the environment, human experience, and social relations.

The third category of professional virtues or excellences is commitments. This category includes, at least for the most part, virtues which have a clear moral dimension. The good engineer will be committed to high standards of trustworthiness and loyalty to employers and clients. The good engineer will also have a commitment to promote human well-being through his or her professional work and to the dissemination of information that allows the public to engage in responsible deliberation about technology policy.

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The Structure and Bonds of Engineering Communities

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Keywords

Engineering communities, Structure of engineering communities, Engineers, Investors, managers, Workers, Bonds of engineering communities, Social reality, Methodological individualism

1. INTRODUCTION

There are a wide variety of communities in society, for instance, scientific communities, engineering communities, and political communities. It is obvious that the population of engineering communities is much more than that of scientific communities and engineering communities play a more important role in society than scientific communities, especially in economy. However, intensive researches on scientific communities have been carried out in fields of philosophy and sociology, while studies of engineering communities have been completely neglected by an absolute majority of philosophers and sociologists.

Purposes and functions of engineering communities are different from those of scientific communities. The former is to discover natural laws, and the later is to create artifacts. The eyes of scientific communities focus on truth, while the eyes of engineering communities focus on value. Theodore Von Karman, an aerospace engineer and educator, says, “Scientists discover the world that exists; engineers create the world that never was.”[1]

2. THE STRUCTURE OF ENGINEERING COMMUNITIES

From the point of view of engineering sociology, the structure of engineering communities is quite different from that of scientific communities. Engineering communities are heterogeneous while the scientific communities are homogenous. The latter comprise only one kind of members, namely scientists, while the former consists mostly of four kinds of members: engineers, investors, managers and workers. In addition to above-mentioned members, engineering communities include other stakeholders.

It is a racy metaphor to compare an engineering community to a machine, for example, an excavator. The structure of an engineering community which consists of engineers, investors, managers and workers, is parallel to one of an excavator which comprises an engine, a gasoline tank, a control panel and a bucket. All four kinds of members are indispensable for an engineering community. We must accept that engineers play a very important role in an engineering community, however if an engineering community comprised only engineers, it could not do any engineering action. So philosophers and sociologists have to devote their attention to not only the roles that engineers play, but also the roles that investors, managers and workers play. Furthermore, philosophers and sociologists must devote their attention to relations among engineers, investors, managers and workers.

3. FOUR KINDS OF BONDS OF ENGINEERING COMMUNITIES

Many economists stand for methodological individualism or ontological individualism. However, it is obvious that an isolated man is unable to carry out an engineering project and human beings have to make up an engineering community in order to carry out an engineering project.

Why and how do human beings make up an engineering community in order to carry out an engineering project?

The engineering communities are bound together by four kinds of bonds. Firstly, the members of an engineering community have to keep some mutual purpose, at least an inferior purpose. So some mutual purposes come up as the first kind of bond, a spiritual bond. The second kind of bonds is capitals. Investors invest money as financial capital, while engineers, managers and workers invest human capitals. Thirdly, members of an engineering community unite by institutions, habits and communication. Last but not least, common knowledge and information are regarded as the fourth bond that holds members of an engineering community together.

4. BASIC ENGINEERING COMMUNITIES AND DERIVATIVE ENGINEERING COMMUNITIES

Engineering communities can be divided into two categories, engineering activity communities and engineering occupation communities. The former comprises firms, companies, project teams or groups, and so on. The latter comprises trade unions, societies of engineers, and societies of employers. The former is basic while the latter is derivative. Considering that occupational communities, such as trade unions, are unable to carry out engineering projects, we regard them as derivative engineering communities. Different from derivative engineering communities, engineering activity communities are regarded as basic engineering communities.

Recently social reality or institutional reality is drawn more and more attention in the field of philosophy [2]. Admittedly, that is a hard nut to crack. However it is certain that we will deepen our understanding or interpretation of social reality through intensive researches on engineering communities.

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The Engineer’s Identity Crisis:
Homo Faber vs. Homo Sapiens

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1. THE ENGINEER’S IDENTITY CRISES

Engineers have at least three identity crises, all related to different branches of philosophy. First, there is a crisis regarding engineering *influence*. Although there was a time when engineering was synonymous with the progress and upliftment of man, the technological society and environmental crisis have raised the question as to whether engineers do more harm than good. The study of such rights and wrongs is that branch of philosophy called *ethics*.

Next, there is a crisis regarding the engineering *role*. Is an engineer a scientist or a manager? Most students who enroll in engineering undergraduate courses have a strong background and interest in science. A practicing engineer on the other hand functions largely as a manager. Also, in some situations, engineers have difficulty in explaining how their role differs from that of a technician or even craftsman. Engineers therefore need an understanding about who they are; in other words, about their *being*. The study of being is that branch of philosophy called *ontology*.

Finally, there is a crisis regarding engineering *knowledge*. Is engineering knowledge theoretical or practical? Most engineering undergraduate courses are filled with theoretical subjects that are largely “mathematics in disguise”. Engineering practice on the other hand is largely practical in nature, and great reliance is placed on established procedures (or “rules of thumb”), specified guidelines (or “codes of practice”) and that indefinable element called “engineering judgment”. Does this mean then that engineering education is a waste of time? The study of knowledge is that branch of philosophy called *epistemology*.

2. THE WIDER FRAMEWORK

Some of the answers to the above questions can be found by identifying tensions and clarifying issues in the wider framework encompassing engineering and philosophy. This framework is represented by Figure 1. The entities on the right hand side are concerned with *understanding*, while those on the left hand side with *useful change*. Recall Karl Marx’s comment that “philosophers have tried to understand the world; the point however, is to change it.” Although it could be argued that philosophy is a more all-encompassing activity than technology [1], the latter was probably prior to philosophy, so that the idea of *homo faber* (man, the maker) is more primordial that that of *homo sapiens* (the wise man).

2.1. Technology versus Philosophy

Anti-technology writers in the second half of the 20th century have charged that technology is dangerous, divisive and dehumanizing. Florman [2] refutes these charges, and also points to the benefits bestowed upon man by technology in areas such as transportation and health, and by the general improvement of the standard of living. Mitcham [1] points out that anti-technology philosophers all contrast modern technology with the pre-modern, reserving their criticism for the former. However, it must be noted that modern movements against some of the ill-effects of technology want to use technology itself to cure those ills.

The roots of the anti-technology attitude in fact date back to Ancient Greece, where “pure speculation” was considered to be a loftier pursuit than utilitarian pursuits. Florman [2] says that this mind-set, combined with the Biblical New Testament emphasis on the spiritual as opposed to the material, has combined to give technology a bad image or low status in Western culture. Thus, in addition to being seen as morally questionable, technology is treated as intellectually inferior. Florman suggests, as least in Western cultures, that engineers dig deeper into their heritage, e.g, the Old Testament, where the ability to perform various skilled crafts is ascribed to the indwelling of the Spirit of God; also the pre-Socratic era, where craftsmanship was held in high esteem by Homer, who gives great technical detail of both tools and materials in the descriptions of the making of Odysseus’ raft and Achilles’ shield [2].

Heidegger is probably a good “patron philosopher” for engineers. On the one hand, he too was strongly suspicious of modern technology, claiming that it destroyed diversity through reductionism [3] – for example modern technology would see both the trees in a forest and the forester as mere “inputs” to a cellulose production process, thus minimizing their intrinsic worth and also any holistic relationship between them. However, Heidegger’s view of the “human way of being” was an instrumentalist one – we “are” and “do” before we “think”, engaged as we are in shared practices involving both “equipment” and others [4].

2.2. Engineering versus Science

While the understanding gained from science has in fact been used to create change by engineers, the sources of engineering knowledge are much more diverse. Vincenti [5] cites many other activities that generate engineering knowledge, such as invention, theoretical and experimental engineering research, design practice, production and direct trial.

One distinction between purely scientific and engineering knowledge is that the former is used for causal explanations, whereas the latter is used for teleological (or purpose-related) information [6]. We could view (engineering) science as the core of engineering design knowledge; a core however that is encapsulated by “rules of thumb” (also called “heuristics”) such as engineering idealizations, margins of safety, design philosophy and design process. Before employing engineering science theories, we have to adopt a particular design philosophy, decide on margins of safety and idealize the real world into a model to which the scientific or mathematical theories can be applied; and all this has to be done within a design process involving collaboration and communication.

The use of “rules of thumb” may result in “unqualified” practitioners being able to perform routine engineering tasks; such tasks would not need the degree of accuracy, precision or sophistication that can be delivered by cutting edge engineering science. However, only those equipped with sound theoretical knowledge can tackle challenging problems from first principles; or know the conditions under which second order effects become predominant. At the same time, engineering science knowledge alone is not sufficient to become a successful engineer in an increasing complex world involving myriads of actors, contexts and interests. Although handling this complexity comes with experience, practitioners could benefit if “systems” models were developed in order to help them process or harness their experience [7].

2.3. Practice versus Theory

Just as engineering was traditionally perceived to be “applied science”, so engineering practice was widely regarded as flowing from engineering theory. However, practice itself is now considered to be a rich source for theory, especially theories regarding the engineering design process itself. Modelling of the design process, as distinct from the product, is a very active research area. There is now a growing acknowledgement that such models should support the human actors rather than replace them. All this will require much input from design practice itself, and the process of engineering design has been equated to theory building.

A broad philosophy of practice is being actively developed [8], with contributions from philosophers, engineers, craftsmen and actors. The attempt is to show that knowledge is very often acquired from practice (perhaps under apprenticeship), rather than from theory alone. Donald Schon [8] contrasts reflective practice with technical rationality, but both approaches are complementary in engineering design [10].

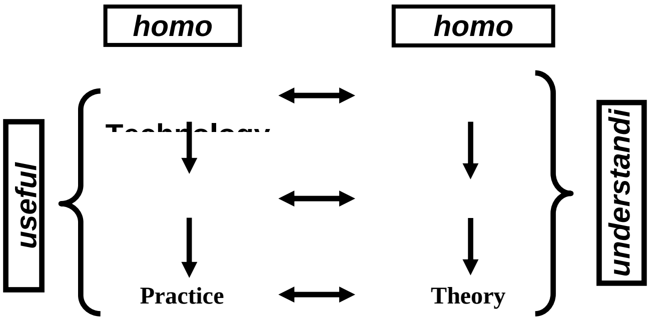

Figure 1 – The Broad Framework

One of the most important “projects” for the future is the development of concepts and tools that will help to formalize practice based knowledge, through the capturing, structuring and processing of such knowledge [11]. The use of knowledge processing tools such as AI may be one way of doing this - e.g. the judgment of an experienced estimator in bid mark-up decisions could be captured in a neural network trained on data from past practice. The adoption of “big picture” systems frameworks could also help - e.g. the collaborative use of a “rich picture” at the conceptual design stage could enhance quality and reduce unintended adverse consequences [7].

3. CLOSURE

Engineers should remain proud of their contributions to society, but seek to become self critical or “suspicious” of technology’s ill effects. They should see engineering as being richer than science, because the former involves holistic interaction whereas the latter is forced to pay “selective inattention” to many aspects of real life problems. They should also develop some philosophical foundations, “soft systems” frameworks and computational formalizations for practice based knowledge, in order to complement the well established theoretical knowledge they are trained in.

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A Rawlsian Approach to Distribute Responsibilities in R&D Networks

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responsibility, problem of many hands, wide reflective equilibrium, procedural ethics, engineering ethics

1. INTRODUCTION

Technological research is increasingly carried out in networks of organizations with different kinds of actors involved. These networks often lack a strict hierarchy and a clear task division. Consequently, decisions are subject to negotiation instead of top-down decision making. This increases the likelihood of the problem of many hands, which is the difficulty, even in principle, to identify the person responsible for some outcome [1; 2; 3]. The occurrence of this problem in R&D is especially undesirable since technologies can have negative consequences, risks and unforeseen side-effects as well, often with high impact (e.g., the use of asbestos, CFCs, DDT, nuclear waste and the greenhouse effect). These future consequences are often hard, if not impossible, to predict with any accuracy beforehand and often only materialize during use, what makes them difficult to connect causally to the actions of one of the actors in the network [4].

The problem of many hands can be conceived as a tension between two moral requirements for a desirable distribution of responsibilities in R&D networks [5]. One is that the distribution ought to be complete in the sense that for each moral issue someone is responsible. The other is that the distribution ought to be fair. Fairness requires that certain conditions are met before an actor can be held responsible [6; 7]. Typical conditions are intentionality, voluntariness, knowledge or foreseeability, causality, and blameworthiness. These conditions are based on the classical notion of individual responsibility. In a collective setting these conditions are difficult to meet. The unforeseeability of future consequences of newly developed technologies complicates the fairness requirements even further. The combination of the collective setting in which technologies are being developed and the unforeseeability of their consequences make it highly unlikely that for every outcome someone can be fairly held responsible. Hence, stressing fairness might result in an incomplete distribution of responsibilities. Given the high-impact of technological risks and side-effects this is undesirable. Not only is it morally unsatisfactory for many people, especially victims and members of the public but often also members of the engineering community, that if an engineering disaster occurs nobody can be held responsible. Maybe more important is the fact that if nobody is held morally responsible for a disaster, it is less likely that people learn from mistakes, to do better in the future. On the other hand, if we stress completeness, in the sense that for each outcome someone can be held responsible, the result might be a morally unfair distribution of responsibilities.

In this paper we propose to approach fairness from a more procedural way to assess whether this is helpful in reconciling the two requirements. If it turns out possible to derive a procedural fairness criterion which is accepted by all people involved, this might help alleviate the problem of many hands.

2. RAWLSIAN APPROACHES

To develop a procedural fairness criterion we use the method of Wide Reflective Equilibrium (WRE), initially developed by Rawls [8], and further elaborated by Daniels [9]. Rawls used the method of WRE in explicating and defending his theory of justice in the context of political philosophy. He tried to develop a criterion of justice that would be agreed upon by all despite the diversity of moral frameworks people endorse. To do so Rawls introduced the so-called ‘original position’, a hypothetical situation in which representatives of citizens are placed behind a veil of ignorance, depriving them of information about the individuating characteristics of the citizens they represent, in order to let them reflect upon and after deliberation agree upon principles of justice that would be acceptable to all. Since the people do not know who they represent, Rawls argued, people would agree on principles of justice that are fair to all. This is what Rawls called justice as fairness. Recognizing the plurality of incompatible and irreconcilable moral frameworks within a democratic society, Rawls later limited the idea of justice as fairness to a procedural conception of justice. People with divergent moral doctrines will most probably not agree on a thick conception of justice but they can overlap in their acceptance of a procedural conception of justice. For these procedural principles to be justified they must cohere with each individual’s background theories and considered judgments. To achieve this, people work back and forth between their background theories, moral principles, and considered judgments – or “layers of morality” as Rawls calls them – and revise them if necessary. When the three layers cohere, people are said to have attained a WRE.

The Rawlsian approach of WRE is particularly interesting because it seems to provide a promising procedure for decision making in situations where people have different moral frameworks. Moreover, by focusing on equilibrium people are encouraged to engage in a deliberative process.

3. METHOD

To apply the Rawlsian approach of WRE a group of engineers, researchers and policy makers was invited to reflect on the distribution of tasks and responsibilities in the well-known engineering ethics case of Gilbane Gold. To simulate the anonymous environment of the Rawlsian 'original position' the participants were invited for a session in the Group Decision Room (GDR), an electronic brainstorming facility which allows for anonymous voting. The participants were asked beforehand to fill in a questionnaire dealing with their moral values and background theories. During the session people were encouraged to discuss points of disagreement together. After the session the participants were asked to give a written justification of the resulting responsibility distribution.

The aim of the GDR session was to twofold:

1. to see whether it is possible to uncover the empirical data required to assess an agreement among participants in terms of reflective equilibrium (methodological objective);

2. to see whether a GDR session could result in a distribution of responsibilities that is both fair and complete (substantive objective).

On the basis of the gathered data the resulting responsibility distribution was judged in terms of the coherence with the moral principles and background theories of the participants such as to be able to see whether it was justified (fair). It was examined to what extent the learning processes, triggered during the GDR session, did contribute to the achievement of a fair and complete distribution of responsibilities. The GDR session showed that it is indeed possible to uncover empirical data required to assess a certain agreement among participants in terms of each individual's WRE. It was also found that the interactive session triggered learning effects. To see whether these learning effects are sufficient to agree on a distribution of responsibilities that is both fair and complete, it is necessary to apply the same method to a 'real case', where the participants all have a stake in the technology or project under consideration. The participants indicated that the latter is an important condition for assigning responsibility.

4. FUTURE RESEARCH

The present application of the WRE approach concerns a hypothetical case with a more or less artificially constructed network. The next step will be to apply the method to a real engineering case and invite all relevant actors participating in the network.

5. ACKNOWLEDGMENTS

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Descartes and Locke at the Drawing Board: Philosophies of Engineering Design

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1. INTRODUCTION

This talk presents findings based on research for a D.Phil in Science and Technology policy, recently awarded, which explored thedifferences in the philosophies of design between two aircraft design teams engaged in the synthetic, conceptual stages of design.

The basic finding of the thesis was that there is not simply one approach to carrying out the early stages of design, but possibly many. In the context of the two teams looked at, the differences between them appeared to be both marked and persistent, to the extent that their work can be characterised as representing two very different philosophies of engineering knowledge. They are referred to as 'Descartes and Locke' as their differing approaches are comparable to the differences between those two philosophers' most familiar ideas.

The two approaches to design put forward in are characterised as being *project-based* and *research-based*, and the presentation of these two philosophical approaches to design forms the basis of the talk, with links to the literature on design and related activities, such as Vincenti (1), Constant (2) and MacKenzie (3), noted.

The research for this work involved extensive interviews with design practitioners in UK industry.

2. THE PROJECT-BASED APPROACH

The project-based approach to design consists of using experience as the basis of design knowledge. Designers attempt to produce, as quickly as possible, a single configuration based on the knowledge gained from experience.

Having produced a preferred configuration, they then focus testing activities around it, to prove its strengths and identify any hidden weaknesses. The results of these activities would be fed back into the selected configuration in order to refine it. In essence, selection precedes a number of variations around a selected concept in order to validate the selection, rather than to inform it before it is made.

3. THE RESEARCH-BASED APPROACH

The research-based approach to design differs considerably from the project-based one. Instead of trying to arrive as quickly as possible at a preferred configuration, the initial step consists of carrying out as wide ranging a series of research and testing activities as possible. These are used to build a design data base. From this data base configurations to be considered are then drawn.

A key point is that it is configurations in the plural - usually more than one will be considered at the same time, often of very different configurations, with the strengths and weaknesses of each considered against criteria derived, in part, from the data base. Selection only occurs after a wide search of the attributes of a wide variation of possible concepts.

4. KEY DIFFERENCES

In the research-based approach designers need to encompass all the possibilities available. Testing activities are intended to produce knowledge that is 'generalisable' over a range of configurations, drawn from the common data base. This is in contrast to the project-based approach, where the knowledge gained from testing is seen to apply mainly to a single configuration.

The project-based approach is aimed at providing as much depth of understanding of a single configuration as possible, given time and resource constraints. The research-based approach, on the other hand, is aimed at providing a validated data base, with configuration studies forming part of the process of validating this. This difference of philosophy lies at the heart of the two approaches to design sketched here.

5. LITERATURE

The two approaches to, and philosophies of, design presented are readily related to the existing literature. Most directly, Vincenti's (1) idea that variation/selection, is *the* engineeringmethod, widely applicable, seems to be challenged by the finding of this research. However, as the research looks at the early stages of design, which Vincenti deliberately chose not to look at, it can be seen as giving results that complement Vincenti's work on analytical design by 'opening up' the synthetic stages of design. In doing so, it also relates to work looking at whether analysis can be the basis of a philosophy of design (4).

Constant (2), too, sees variation/selection as central to the engineering method, which he suggests forms the basis for communities of practice in engineering. However, as the differences between the two teams persisted over many years, despite the superficial similarities of education, experience and purpose between them, the idea of a community of practice must be challenged by the fundamental differences of philosophy illustrated in the talk.

Such differences do, however, serve to reinforce MacKenzie's (3) view that major differences can exist between groups within the same ostensible 'community', working on the same basic technology, and add to his view that the institutional framework within which engineering takes place is important. The implication is that for the customers of the design teams involved, understanding the philosophies underpinning their work is important in being able to judge them against one another.

6. SUMMARY

In this talk the two design teams' philosophies are characterised as representing Descartes and Locke in their approaches, in order to both highlight the differences between. Descartes is linked with the research-based approach to design, with inductive rationalism seen as the basis of this approach. Locke is linked to the project-based approach, with experience seen as the key. Anyone who understands the differences between rationalist and empiricist philosophies can be helped to understand the differences between the two design teams by this analogy.

Additional work, currently under way as a follow up to the D.Phil research, is included at the end of the talk. This illustrates how the activities undertaken at the design stage of engineering impacts later on, in the development, manufacture and use of major engineering systems such as military aircraft. This allows the significant implications of the differences between design philosophies to be further illustrated.

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A Polanyian Perspective of Breakthrough Engineering Innovation

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1. BACKGROUND

We live in the age of the knowledge worker, with innovation their responsibility [1]. In particular, as knowledge workers, one of the most important roles of engineers in industry is to develop innovative new products and processes to either increase revenue or decrease cost. While some have begun to consider how engineers know [2], most practitioners and researchers of innovation carry unarticulated assumptions about this topic.

While variations exist, the innovation literature offers two basic categories of strategies for innovation, both of which reflect underlying, and most likely unexamined, philosophical assumptions and puzzles about what knowledge is and how you get it – that is, epistemology. One of these strategies is a certain, methodical process that assumes that knowledge is explicit information that may be systematically accessed by following a rather strict, linear method; the Stage-Gate® Process [3] (SGP) is an example of such a strategy. The other could, by contrast, be construed either as more skeptical or more creative, but it assumes that we can not grasp how innovation really occurs; the Fuzzy Front End [3] (FFE) is an example of such a strategy.

What we find in practice, however, is that such SGP and FFE perspectives – and, thus, perspectives of certainty and skepticism – independently and collectively are, in fact, insufficient to describe how breakthrough corporate innovation actually occurs. Further, those expert and accomplished in such matters in industry, both engineers and executives alike, find both extremes somewhat troubling. This leads us to seek another, more accurate means of describing it.

The research of Griffin, Price and Vojak [4], conducted over the past six years and based on over 125 hours of in-depth interviews as well as a large sample survey, has led us to a clearer understanding of how corporate innovation occurs in practice. This research investigates individuals who have repeatedly conceived and commercialized breakthrough new products in large, mature engineering-intensive firms. These so-called serial innovators and technical visionaries (SIs/TVs) exhibit a combination of broad and deep technical skills, unique insight into customer needs, the creativity to see the connections between the two, a political savvy that gets their projects considered for commercialization, and the facilitative capability to shepherd the innovation through the organization and into the marketplace. In many respects, they transcend – that is, they operate more flexibly and at a higher level than – more traditional innovation processes, such as the SGP. Further, the innovation processes that SIs/TVs employ are more defined than the relatively open-ended perspective provided by the concept of the FFE. Collectively, these characteristics make SIs/TVs unique and powerful, and permit them to have significant financial impact on their organization. These characteristics also suggest that an epistemology different from that represented by either the SGP or the FFE is at work.

2. THE CONNECTION BETWEEN OUR RESEARCH INSIGHTS AND POLANYI'S EPISTEMOLOGY

Having argued that: (1) innovation management and its literature is traversing a path consistent with, if not necessarily influenced by, philosophical considerations of what we can or can not know and (2) currently-held, unarticulated perspectives of certainty and skepticism regarding innovation are insufficient to describe what is observed in the most successful practice of engineering innovation, we appeal to the insight of Michael Polanyi [5], the 20th-century physical-chemist-turned-epistemologist. A respected scientist in his own right, Polanyi understood the epistemological ramifications of his success in the lab. He understood that: (1) if knowledge is restricted to being explicit information impersonally and passively transferred, no scientific discovery could ever occur and (2) his insight conflicted with this dominant philosophical tradition of science as detached observation. Philosophically, he linked this assessment with the ancient Meno Dilemma [6]. Polanyi felt that the problem was significant enough for him to step away from a successful career in science to develop a fresh epistemology.

Many correctly associate Polanyi's work with the proposal of the concept of tacit knowledge and the idea that "we can know more than we can tell" [5], but misunderstand, or miss entirely, the sophisticated and helpful structure that Polanyi identified as characteristic of all efforts to know. The articles of reference [7] – while very insightful in many respects – are examples of how much of this richness, described next, is, at times, missed.

All achievements of knowing involve creative and active integration that has the individual relying on inarticulable subsidiary clues to focus on an eventually identifiable pattern. We note that the SIs/TVs that we have observed do just this. They simultaneously hold fast to multiple technical domains, as well as to customer, market, finance and manufacturing insights, while having the vision to 'see' the innovative concepts that 'connect the dots' within and between these several, and often disparate, domains. In the language of Polanyi's epistemology, SIs/TVs, these exemplary engineering innovators and visionaries, exhibit 'from-to' tacit integration – 'from' an immersive ('indwelling', per Polanyi) subsidiary awareness of the various elements of technology,

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customer, market, finance and manufacturing, 'to' a focal awareness of the innovative product or process concept that coherently takes into consideration all of the opportunities provided by, and also all of the constraints imposed by, the subsidiary elements. Put another way, they do not look 'at' the elements of technology, customer, market, finance and manufacturing; instead they look 'through' them, enabling the SI/TV to 'see' the innovative concept. Polanyi illustrates 'from-to' tacit integration variously, such as by considering how one recognizes a person's face among a thousand while not being able explain how this is so, how a blind person navigates using a cane, or how a 3D stereoscope functions.

3. A POLANYIAN ILLUSTRATION OF ENGINEERING INNOVATION

Noting that Esther Meek's [8] discussion of viewing a Magic Eye® image [9] as an act of Polanyian knowing (i.e. discovery of reality) is so strikingly similar to the type of knowing that we have observed from SIs/TVs in the act of innovating, we employ it here to illustrate our research results. Its value lies in that this perspective goes beyond either and both the certainty of the SGP and the skepticism of the FFE, and provides a new and fresh illustration of corporate innovation actually practiced by the most successful corporate engineers. The key element of this illustration is the 'from-to' viewing, through the 2D surface pattern, that is required to see the embedded 3D image (analogous to the 'connecting the dots' systems thinking observed in the act of innovation as described by the SIs/TVs).

While 'from-to' tacit integration is at the core of this illustration, our presentation also will address how many of the other features of viewing a Magic Eye® image illustrate other aspects of extraordinary corporate innovation that we have observed in the actions of SIs/TVs, including: the multiple perspectives of binocular viewing (analogous to the multiple domains of technical and business knowledge preparation that SIs/TVs bring to innovation), the apparent randomness of the 2D surface pattern (analogous to the highly complex, ambiguous and apparently random data that SIs/TVs confront), the perceived 3D image itself (analogous to the simplified, insightful, innovative solutions that the SIs/TVs seek), and the curiosity, patience and sense of expectation required to view the 3D image (characteristic of the SI's/TV's personality of anticipating success).

4. POLANYI'S 'FROM-TO' TACIT INTEGRATION AS A TIMELESS VIEW OF ENGINEERING INNOVATION

A significant implication of our application of Polanyi's work to engineering is that we see the engineer's innovative output as a skilled creative achievement (not a random association, not a technical method) that emerges from the tacit integration of a cross-disciplinary range of subsidiary clues that are fully expected to vary over time. Viewing innovation in this manner suggests that Polanyi's epistemology represents a timeless view of engineering innovation, rather than the trends of corporate innovation themselves (such as disruptive innovation [10], radical innovation [11], or open innovation [12]) [13].

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Virtual Machines in Philosophy, Engineering & Biology

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Architecture, causation, implementation, information-processing, biology, philosophy, psychology, robots, self-awareness, self-control, supervenience, vertical modularity, virtual machine, virtual machine functionalism .

INTRODUCTION

A machine is a complex enduring entity with parts that interact causally with one another as they change their properties and relationships. Most machines are also embedded in a complex environment with which they interact. A *virtual machine* (VM) has non-physical parts, relationships, events and processes, such as parse trees, pattern matching, moves in a game, goals, plans, decisions, predictions, explanations and proofs.

The concept of a virtual machine, invented in the 20th Century, (not to be confused with *virtual reality*) is important (a) for many engineering applications, (b) for theoretical computer science, (c) for understanding some of the major products of biological evolution (e.g. animal minds), and (d) for gaining new insights into several old philosophical problems, e.g. about the mind-body relationship, about qualia, and how to analyse concepts of mind by adopting the design stance in combination with the notion of an information processing *architecture* [1,2]. Analysing relations between different sets of requirements (niches) and designs for meeting the requirements exposes a space of *possible minds* (for animals and artifacts), raising new questions about evolution, about future intelligent machines, and about how concepts of mind should be understood.

Most philosophers, biologists, psychologists and neuro-scientists completely ignore VMs, despite frequently (unwittingly) using them: e.g. for email, spreadsheets, text processing, or web-browsing. Academic philosophers generally ignore or misunderstand the philosophical significance of VMs (in part because many assume VMs are finite state machines). Pollock [3] is a rare exception. Dennett often mentions virtual machines, but claims they are merely a useful fiction [e.g. 4, note 10]. Events in useful fictions cannot cause email to be sent or airliners to crash. The idea of a VM can significantly extend our thinking about problems in several disciplines and pose new problems for future empirical and philosophical research.

WHAT ARE VIRTUAL MACHINES?

The idea of a VM had (at least) four sources (a) the demonstrations of universality of certain sorts of machine (e.g. a Universal Turing Machine can implement many other machines as virtual machines), (b) engineering problems related to sharing scarce resources between different processes running on one computer, (c) problems of portability and modularity of code for software systems, and (d) the design of layers of functionality for transmission networks. The common idea is that structures and processes can exist and interact in ways that require physical implementation, where the precise details of the physical implementation can vary from time to time across machines and even within one machine. Often VMs are layered, with VM^1 implemented in VM^2, implemented in VM^3, etc. The existence of causal interactions among VM events and between VM events and physical events (e.g. events in a word processor and events on a computer screen) challenges many (all?) philosophical analyses of supervenience and of causation, but the latter is a topic for another occasion.

Many issues discussed by philosophers (e.g. issues about how mental concepts work and about relations between mind and body, such as supervenience) require adoption of the design stance, using the notion of a VM in which enduring concurrent non-physical (but physically implemented) sub-processes interact with one another and with physical entities. Compare: analyses of concepts like 'iron', 'carbon', 'water', 'rust', 'acidic', 'burning' are much better done using a good theory of the architecture of matter than simply using pre-scientific ideas.

“Virtual Machine Functionalism” (VMF) denotes a type of functionalism that refers to virtual machines that contain many concurrent interacting processes, discrete and continuous, synchronised or asynchronous -- unlike conventional Functionalism, usually explained in terms of a simple finite state machine. See [1,2] and my 'talks' website for more details.

SELF MONITORING AND CONTROL

A VM provides a level of abstraction that avoids the need for a designer/maintainer to represent and reason about the vast complexities of the underlying physical mechanisms (molecular, electronic or neural). The same features make VMs important for complex systems that monitor and control themselves: they share some requirements with their designers!

This design strategy works only if: there is a *good* (e.g. reliable, robust, flexible) implementation for the VM, and the VM includes mechanisms enabling relevant states and processes to be sensed and modulated (e.g. blocking email from particular addresses). Identifying requirements for good virtual machines in biological organisms. future robots, and complex control systems (e.g. chemical plants) is a multidisciplinary task for philosophers, engineers (including roboticists), biologists and psychologists.

One requirement is that for organisms reproducing in unpredictably changing environments, some virtual machines need to grow themselves partly under the influence of the environment, rather than being fully specified genetically – see [5]. That's how 3-year olds can play computer games: something none of their ancestors ever did at that age.

Growth of an architecture is different from learning in a fixed architecture with a uniform learning mechanism. Some new mathematics may be required to specify such processes.

BIOLOGICAL VIRTUAL MACHINES

Conjecture: Biological evolution 'discovered' the importance of virtual machines long before humans did, and produced many kinds of virtual machine that we have not yet identified or understood.

In doing that, evolution may well have solved far more design problems (=engineering problems) than we have so far identified. Examples we already know about include homeostatic systems, immune systems, perceptual systems, learning systems, many kinds of monitoring, control and repair systems, and social systems. Much work still remains to be done finding out what the problems were, i.e. what the requirements were against which the designs were evaluated (e.g. by natural selection mechanisms), and what solutions were found. A better understanding of the *requirements* may help to direct more fruitful research into the designs and mechanisms. This can be contrasted with current biologically inspired AI/Robotic research (and some neuropsychology) which often attempts to model supposed mechanisms without finding out what problems biological designs actually solved.

In [6] McCarthy discusses conjectures about the problems evolution solved in producing humans, some of which will also be problems for intelligent machines.

LIMITATIONS OF SUCH SYSTEMS

A consequence of the use of virtual machines, important for philosophy and psychology, is that self-monitoring systems that use the design features described above gain practical benefits (from 'vertical' modularity and reduced complexity of control and monitoring). The price is inherently limited self-knowledge and self-control, since implementation details are inaccessible.

These limitations may not matter in most normal conditions (if the design is good) but things can go badly wrong in abnormal conditions.

This sheds new light on philosophical discussions of qualia, their ineffability, their causal powers, the alleged impossibility of being mistaken about them, the nature and limits of introspection, free will, etc. It can also shed light on some possible types of mental/cognitive dysfunction caused by injury, disease, genetic abnormalities or even abuse. In particular it becomes important to distinguish problems with physical causes from problems that exist at the VM level (like software, as opposed to hardware, bugs in machines). This can be very difficult to do. Some genetic abnormalities produce a tangled mixture of hardware (wetware) and VM dysfunctions.

VMS FOR INTELLIGENT MACHINES

There are also engineering implications: if use of VMs is needed for sophisticated autonomous machines that monitor and control themselves, and which need to be able to adapt to and cope intelligently with unforeseen situations, and reach practical decisions in reasonable times, then they will have some of the failings that we find in biological systems with such designs (e.g. humans). See http://www.cs.bham.ac.uk/research/projects/cogaff/talks/#talk51This raises ethical issues that I shall not discuss now, but designers will need to.

CONCEPTUAL IMPLICATIONS

We need to understand how VM architectures vary. Concepts that are appropriate for describing such complex systems are different for different virtual machine architectures. E.g. a computer operating system VM that never allows time-sharing or paging can never get into the state described as "thrashing" on a multi-processing system. Similarly an architecture that does not support formation and use of predictions would be incapable of getting into a state of being surprised. (It is very likely that the vast majority of animals are incapable of being surprised, despite apparent 'surprise behaviour' – often an evolved automatic reaction to sudden danger, etc.)

So, philosophers interested in analysing mental concepts need to learn to do new kinds of architecture-informed conceptual analysis, both

> (a) to explicate and improve on our existing concepts of mind (e.g. believes, desires, intends, likes, imagines, expects, learns, understands, values, enjoys, dislikes, fears, cares, honest, delusion, self-deception, personality, multiple personality, etc. etc.), and
>
> (b) to work out which sorts of mentalist concepts are relevant to future machines (most of which will, at least in the short run, have far less complex VMs than humans do, which means that the set of concepts that can aptly be used to describe them will be different in important ways – contrary, for instance, to the assumptions of current researchers claiming to build "machines with emotions").

This requires us to extend Ryle's notion of 'logical geography' with a deeper notion of a 'logical topography' that can support different logical geographies, as explained more fully in http://www.cs.bham.ac.uk/research/projects/cogaff/misc/logical-geography.html

CONFUSIONS ABOUT EMBODIMENT

The recent emphasis on embodiment in AI, Cognitive Science and Philosophy of mind has mostly involved a failure to understand how the physical morphology and sensorimotor interfaces of an information processing system relate to the variety of virtual machine layers that may coexist in one system, where some layers are far less constrained by the details of their embodiment than by complex features of the whole environment in which they are embedded and which they need to interact with, think about and understand.

That is why seriously physically disabled humans can, with appropriate help, learn to think and communicate like most humans, despite missing limbs, cerebral palsy, blindness, deafness, etc. which seriously limit their physical interactions with the immediate environment. (Examples include: Alison Lapper, Helen Keller, Stephen Hawking, grown up thalidomide babies, etc. Gender differences are not relevant to this point.)

Consequently, machines (robots) with very different physical forms and physical capabilities can, in principle, if their virtual machines are appropriate, share a great many forms of representation, concepts, concerns, values, thoughts, beliefs, hopes, fears, etc. with humans -- and be capable of communicating with them, despite great physical differences.

But before we have any hope of producing such machines, we need a far deeper understanding of (1) the problems evolution solved (the requirements for biological VMs), (2) the design options for solving those problems and the tradeoffs between the options. Philosophers will need to learn to think about tradeoffs and designs as engineers do, and engineers will need to learn to do conceptual analysis in order both to clarify their objectives and to avoid misdescribing what they have achieved, thereby invoking the scorn of McDermott [7]. Self-aware machines will need to use VMs to understand themselves.

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Constructive emergence: a computer scientist looks at philosophy

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Computer science, philosophy, reduction, emergence, supervenience, conceptual grounding, thought externalization.

1. WHY DO PHILOSOPHERS BUT NOT COMPUTER SCIENTISTS FIND EMERGENCE MYSTERIOUS?

My paper last year [1] compared styles of thought in computer science and engineering. This year I compare computer science with philosophy. (As you might guess, I'm a computer scientist. I acknowledge from the start that this paper is a bit "in-yourface.")

Since philosophy is such a broad discipline, I'm limiting myself to emergence, a topic about which I've recently written— for example, [2] and [3].

Emergence is the notion that higher level phenomena can be autonomous from the underlying phenomena on which they are based. I claim that a computer science approach to emergence resolves the fundamental issues. Yet philosophers still see emergence as mysterious. As recently as April 2008 the introduction to a collection of articles about emergence edited by Bedau and Humphreys [4] asserted that "the very idea of emergence seems opaque, and perhaps even incoherent."

In computer science, emergence is neither opaque nor incoherent. It is a fundamental software design principle—the intuition behind such ideas as software platforms, levels of abstraction, abstract data types, object oriented programming, the distinction between a specification and an implementation, APIs, etc. The notion that higher level phenomena may be autonomous of a lower level base is also widely expressed in the philosophical literature. For more than three decades, functionalist philosophers such as Fodor [5] have argued for the autonomy of the special sciences—any science other than physics. The very *existence* of the special sciences testifies to reliable macro-level regularities … Damn near everything we know about the world suggests that unimaginably complicated to-ings and fro-ings of bits and pieces at the extreme *micro*-level manage somehow to converge on stable *macro*-level properties. …

But Fodor continues (somewhat paraphrased): The "somehow" really is entirely mysterious. Why should there be (how could there be) macro-level regularities *at all* in a world where, by common consent, macro-level stabilities have to supervene on a buzzing, blooming confusion of micro-level interactions. What I find mysterious is not the fact of emergence but Fodor's bafflement about it. But Fodor insists he doesn't know why.

So, then, *why is there anything except physics*? … I expect to figure out why … the day before I figure out why there is anything at all.

It's not just Fodor, Bedau, and Humphreys who are puzzled by emergence. It has provoked philosophical debate for years. For computer science, emergence is our bread and butter. Every software application is an implementation of emergent phenomena.

Microsoft Word, for example, implements such emergent abstractions as paragraphs, words, fonts, pages, documents, etc.

These concepts and the rules that govern them are autonomous from the rules that govern the underlying levels. Depending on one's focus, the underlying level involves logic gates, or machine instructions, or programming language constructs, etc. None of these has anything to do with documents, paragraphs, words, characters, or fonts. Yet there is no mystery about how these autonomous higher level abstractions come to be. Computer science is largely about turning operations performed by logic gates into emergent Microsoft Word abstractions.

A useful example of emergence is a Turing machine implemented within the Game of Life. (See [2].) Turing machines compute functions, and Turing machines are bound by computability theory. But functions and computability theory were developed long before Conway invented the Game of Life. It seems reasonable therefore to say that they are autonomous of the Game of Life. Yet nothing happens on a Game of Life grid other than that cells go on and off as a consequence of the Game of Life rules. So a Game of Life Turing machine would seem to be an easily understandable and paradigmatic example of emergence: autonomous higher level phenomena resulting from lower level activities. (This also seems to me to illustrate why multiple realizability is not relevant: autonomy exists without it.) But Fodor [5] dismisses emergence of this sort.

2. DIFFERENCES BETWEEN PHILOSOPHY AND COMPUTER SCIENCE

It is not news to philosophers that Turing machines can be implemented within the Game of Life. Dennett [6] noted this in a widely cited paper more than a decade and a half go. Yet emergence is still seen as a philosophical puzzle. In attempting to understand why, I've examined some of the relevant philosophical literature. I've noticed two important differences between computer science and philosophy.

One is conceptual and terminological. A number of concepts are used similarly but not identically in philosophy and computer science. Pairings include: emergence/abstraction, reduction/ implementation, autonomy/specification-implementation, kind/type, causality/execution, individual/object, and supervenience/ functional dependency.

A second difference concerns the degree to which philosophers and computer scientists feel themselves obliged to ground their thinking. Computer science is grounded by the requirement that ideas must (usually) execute as software. There is rarely a question about what a term means: at worst it means what the software that implements it does. Computer science is a constructive discipline. We build new concepts on top of existing concepts, which themselves are grounded by executable software.

As a result, computer science discussions are almost always framed in terms of well defined and well understood concepts. To my computer science eyes, many philosophical discussions don't seem to be similarly grounded. They often seem to be about theories expressed using terms that themselves are not well understood. (That's my guess about why philosophers so often claim to find mistakes in each others' papers: "Y is wrong about Z" or "X is wrong about Y being wrong about Z.")

This is not to say that philosophers aren't careful. Philosophers have been so careful that supervenience, for example, has probably a dozen definitions. The related computer science concept is functional dependency: a set of database attributes is functionally dependent on another set if the latter determine the former. The issue for computer scientists is not what functional dependency means (or should mean) but when to declare a functional dependency. A database that includes attributes for both molecular descriptions and appraised value would simply not declare the latter functionally dependent on the former. Another example of a theory built (in my view) on uncertain foundations is the near universal agreement that "the mental supervenes on the physical." Not only does supervenience seem not to be solidly defined, but (it seems to me that) we don't understand the properties of either the mental or the physical well enough to talk about whether a functional dependency exists between their properties. Presumably the claim isn't really about supervenience but something to the effect that dualism is wrong.

Supervenience may not even be the best way to establish that since all it guarantees is co-variation. The notion of scientific reduction also illustrates the differences between the two disciplines. Reduction has an enormous and growing philosophical literature. A far as I can tell there is no philosophical consensus about how to define it. In contrast, the computer science notion of implementation, which is something like our version of reduction, is well defined. This is not to say that computer science's implementation resolves all the philosophical issues associated with reduction. In fact the philosophical literature distinguishes between what is called realization— which is also like our implementation— and reduction.

Functionalists claim that realizations may exist when (or when multiple realizations exist as evidence that) reduction is not possible. For people like Fodor [7] the difference seems to be that reduction requires realization along with a simple mapping from natural low level kinds to natural high level kinds. (The philosophical notion of a natural kind is also quite unsettled. In Computer Science we call kinds "types," a fairly well defined concept. We don't talk about natural types.)

A current movement in philosophical reduction shows an interest in models and mechanisms, for example [8] and [9]. Mechanisms and models are quite compatible with the computer science understanding of reduction as implementation.
(See [2] and [10].)

3. SUMMARY

When computer scientists talk about functional dependency, implementation, and types, we know what we mean. When philosophers talk about supervenience, reduction, and kinds, things seem far less settled. Perhaps it isn't so surprising after all that a concept like emergence is well understood in computer science but problematic in philosophy.

Much of computer science is about developing tools to express (i.e., externalize) one's ideas in a concrete operational form.
(See [3].) Much of philosophy is about finding and expressing ideas that seem right. Neither discipline can capture conscious meaning: ideas once expressed are just symbols. But the discipline of having to operationalize those symbols as software often clarifies the ideas and helps one decide whether a particular way of expressing them is really what one wants to say.

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A Philosophical Model of the Relationship between Structure and Function in Engineering Design*

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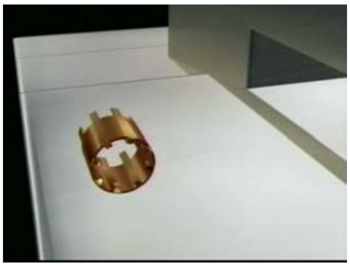
Key words: Structure and function; description of Class Function; Underdetermination and Realizability Constraints; philosophy of design

The relationship between structure and function raises a hard problem in Philosophy of Technology and engineering design. From a logical perspective, Kroes came to the conclusion that there must be a logical gap between structure and function[1]. From an epistemological perspective, functional knowledge is not provided by structural knowledge[2]. From an ontological perspective "a hard problem" is raised[3]. From an engineering perspective, it is not clear how to describe the relation between structure and function in the contexts of engineering design. "Creativity in design … is something that needs to be examined in more detail"[4].

My strategy is to introduce a new mode of description, that of the Class Function description which I propose to instead of the structural and functional descriptions. The new description relates to structural and functional descriptions but is different. It depends on the auxiliary plane and on the conception of Class. Such an auxiliary plane does not exist in reality but is just a pragmatic and mathematical tool which is useful for analyzing the relationship between two natures. The conception of Class comes from the conception of theory of Object-Oriented Programming, which can be regarded as a special representation of kinds of artifacts. I will show how, when structure and function are each in their own way related to a specific context of human action (namely with structure relating to the context of design and function relating to the context of use), structural and functional descriptions may be represented by descriptions in terms of Class Function.

I will discuss a case about a creative mold design which comes from a documentary that was made by the NHK (the Japanese Broadcasting Corporation) in 2005. This case depicts a client asking a factory to design and manufacture a kind of mold that can produce a circular copper annulus from a material known as copper plate. Circles, in the engineering community and in the mold design industry, are regarded as the most difficulty targets to achieve. At first, it was failed when they chose traditional design method. After studying similar case records, an engineer finally found the problems and corrected them by his personal experience and knowledge of know-how.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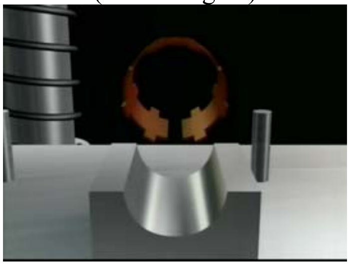
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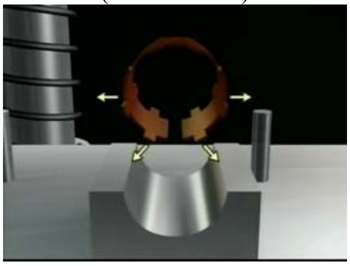
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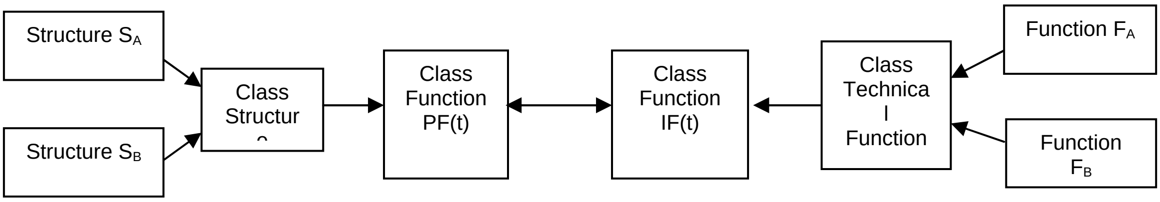
On the basis of the discussion of mold design, I propose a general model of the relationship between physical structure and function.



The conditions for judging a relationship built between structure and function depend on the requirements of function and what a client wants. The most serious condition, theoretically, is that the curves of PF(t) and IF(t) fit each other perfectly. It is the minimum condition for judging the relationships created, because the outcomes satisfy the goals of the client, that is, the end of PF(t) identifies the end of IF(t) according to practical reasoning. This model can explain the phenomena of Underdetermination and Realizability Constrains.

Although structural descriptions cannot be deduced from functional descriptions, and vice versa, these two descriptions can be related with the help of the third description, i.e. the description of Class Function by which the phenomena of Underdetermination and Realizability Constraints can be explained. The logical gap between two natures implying that structural description cannot be deduced from functional description and vice versa still exists, because such relationship with the new model only represents a practical approach but not a logical approach.

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Normative crossover terms
The ethos of an ultrasound screening programme

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INTRODUCTION

In course of the development of the STS field (Science and Technology Studies), mainly during the 1980s and 1990s, its proponents have tended to bracket off normative questions. An important part of the explanation of why this happened concerns the way STS scholars came to undermine the crucial distinction between the technical and the social. The blurring of this distinction implied a critique of the way both epistemic and ethical-political normative issues had been identified and scrutinized by scholars, but have been criticized for having left us without much of an alternative. The challenge of restoring a normative perspectives in the field of STS are connected to the joint work of rethinking the two, theoretically and methodologically.

We need normative terms that "cross-over" the issues we recognise as respectively epistemic and ethical-political. The widely used notion of (socio)technological system is a notion that defines technologies in ways that cross over the social and the technical. In my view, it is Bruno Latour's, or more broadly the actor-network, approach that gives weight to this notion. Latour borrows the crossover notion from genetics having chromosomal crossover in mind. Crossover terms in Latour's analogy are to capture the exchange, mixing and mutual blending of the social and the natural. The "thing" under consideration, in this perspective, is not the isolated technological artefact, but rather the dynamic actor-network that mediates the actions being done.

Given this perspective, which I take as my point of departure, I seek to explore ways of articulating how the normative evaluation of the actor-network in question are being shaped. Actor-network type of approaches needs to include a descriptive language that makes it possible to articulate and trace the shaping and maintenance of the distributed and aggregated point or purpose of the actions being mediated through the technological system. I believe a notion of ethos may serve such a normative cross-over purpose. I draw on the work of the moral philosopher Charles Taylor, suggesting we try to make sense to notions like the ethos of technological system or the ethos of an actor network. Reference to ethos may provide a short-cut reference to traces of human evaluation embedded in an actor-network. Human agents, as analysed by Taylor, cannot escape evaluating their own actions, although the evaluation may be weak or strong, that is, even crucial decisions we live by may be more or less well explicit deliberated or more or less well argued. The notion of ethos of a technological system draws attention to immanent evaluative traces of human action.

THE ETHOS OF AN ULTRASOUND SCREENING PROGRAMME

I have found a context for discussing the notion of ethos in medicine. I discuss a normative controversy that took place at my university in Norway in 1999-2000. It is a story about a research project that were to evaluate the medical and social impacts of shifting the ultrasound investigation of pregnant woman from 18'th to 12'th week of pregnancy (witch is the legal abortion limit). The shift was motivated by new, and more powerful visual images that were to be evaluated simultaneously. It was a project that potentially could affect every pregnant woman in Norway since almost everyone accept the ultrasound investigation they are offered, it has in practice become a screening programme.

The controversy became a national affair as the Minister of Health intervened in the project by publically questioning the worth of the research project. This question re-opened and twisted the old ethical controversies of the screening programme that had run under the heading of "medicalisation" of pregnancy as well as "eugenics". An important and interesting part of the public debate was also the question of freedom of research on the one hand and the issues of control of technology on the other hand (and the problem of ethics arriving to late). The controversy culminated in a closure of the research project.

To understand and evaluate the role such controversies play in the research process, we need to find ways of understanding normative evaluations as part and parcel of, in this case, the technological system of the ultrasound screening programme. The notion of ethos seeks to capture how evaluations of worth play a role in mediating, maintaining as well as destabilising a technological system, without compromising crucial insights of in the actor-network approach.

THREE ELEMENTS OF THE ETHOS

The story of the controversy of the research project provides a context for my clarification of notion of the ethos of the screening programme. I focus on three connected elements.

1) Ethos is a moral term that goes back to the Greek discussion of the moral character of man. As a point of entrance to the notion of the ethos of an actor-network, one may say that the term refers to the moral character that a practice like the screening programme has qua human practice - without witch there would not be a technological system. As such, judgements of worth of the screening programme needs to be seen as part and parcel of how the programme is performed and maintained.

The ethos of the screening programme, capturing what it is as something good and desirable, may however be fragmented, more or less consistent and articulated. The Ministers intervention had a crucial effect on the course of events. It was a type of social intervention that could be seen as a way of testing the social robustness of the programme. The minister intervention sparked a debate that could not have become so vivid if there was nothing there to be sparked, something that was crucial and important for the persons being engaged in the debate. The ethos of the screening programme was not totally in the hands of the researchers, it was rather something they had to deal with.

2) Ethos is something that is temporally shaped. Ethos, as used as a technical term in rhetoric, is a term that urges the analyst to scrutinise how the speaker's ethos (qua trustworthy speaker) is temporally constructed, maintained or deconstructed through the speech act. The ethos of the screening programme, as the notion is used here, should also urge the analyst to scrutinise how the technological system was brought together in order to establish a stable technological system people are willing to rely on, put their trust in and live with. In this case the notion of ethos draw attention to a discussion of the desirability of the research project in terms of whether or how the research project possibly could pave the way for radical changes in the world. Changes that for instance would impose a set of novel choices or responsibilities on the becoming parents.

3) The ethos of the screening programme is temporally shaped – both as a reliable and desirable technological system, but not only by humans. The history of the program draws attention to the role non-humans play in the process of the shaping the ethos. The focus on the temporality of the process allows us to say in a meaningful way that material agencies are morally relevant agencies (without imposing a symmetric descriptive language of humans and non-humans). The very existence of a diagnostic tool may change the personal storyline of individuals as well as open up new issues, like questions of who should possibly make decisions of whether or not someone should be able to get access to knowledge.

On Engineering Meanings of Functional Decomposition

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Keywords
philosophy of engineering, functional decomposition, capacities

In this paper I employ Cummins' function-as-capacity notion [1] to analyse engineering descriptions of functional decompositions in the Functional Basis (FB) methodology of Stone and Wood [2] and the Multi Level Flow (MFM) modelling methodology of Lind [3]. Functional decomposition refers to a breakdown of functions into sub-functions, describing a part-whole relationship on the level of functions. This analysis shows that functions in both methodologies correspond to capacities. Besides this common ground however, I argue that the meaning of functional decomposition in these methodologies is divergent, specifically: 1) not all sub-functions in FB functional decompositions correspond to capacities that are functional, whereas sub-functions in the MFM do, 2) sub-functions in the FB correspond to physical capacities of technical systems, whereas sub-functions in the MFM either correspond to physical capacities of technical systems or capacities of agents qua user actions, and 3) sub-functions in the FB describe capacities of physical processes, whereas the sub-functions in the MFM that correspond to physical capacities either describe capacities of processes or capacities of objects.

These results corroborate the view of Bucciarelli [4] on the multiplicity of conceptual perspectives in engineering design practices, and the views of Simons and Dement [5] on the multiplicity of part-whole relations of artefacts. The results presented in this paper also extend the analysis of Simons and Dement. They confine their discussion of part-whole relations to analysing functionally defined physical parts or "functional components", whilst the analysis presented here also suggests a multiplicity of part-whole relations on the level of functions.

1. CUMMINS FUNCTIONS

In Cummins' approach, functions correspond to dispositions/capacities (Cummins equates dispositions with capacities. I use the term capacity in this paper). Capacities refer to regularities in behaviour, special to objects having the capacity, which obtain in virtue of some special fact(s) of or (structural) features about the object. To explain these behavioural regularities is to explain how manifestations of a capacity are brought about given certain requisite "precipitating conditions" – the occurrence of certain events (p. 758). In Cummins' approach, functions are ascribed to items (objects or processes) in the context of an analysis or "analytic explanation" (p. 762) of a capacity of a containing system – coined the analyzed capacity – into other capacities of the system or component parts of the system – coined the analyzing capacities. In an analytic explanation, the analyzing capacities are ascribed functions if they causally contribute to the analyzed capacity of the containing system. Cummins' approach is generic, in which functions can be ascribed to both physical objects and processes as well to actions of agents.

2. FB AND MFM FUNCTIONAL DECOMPOSITIONS

Both the FB and MFM methodologies model functions as operations on material, energy, and signal or information flows. In the FB, a standardized set of operations and flows, coined a Functional Basis, is employed to represent sub-functions. In MFM a (smaller) set of operations is defined for material, energy and information flows to represent sub-functions. Although the representational format used by the methodologies is similar, distinctions emerge in their meanings of functional decomposition.

The FB methodology is a functional modelling approach, focussed on the electromechanical and mechanical domains, that allows designers to model overall product functions as sets of interconnected sub-functions. The approach aims to support various engineering tasks, such as providing functional descriptions of existing products and engineering designing of new products [2]. An overall product function refers to a general input/output relationship defined by the overall task of the product, represented by a black-boxed operation on flows of material, energy and signal. These black boxed operations on flows are derived from customer needs. A functional decomposition specifies chains of operations on flows (sub-functions) for each black box input flow that transform these black box flows step by step into output flows.

The MFM methodology is a functional modelling approach that is developed for modelling the goals and functions of industrial plants. The approach aims to support diagnosis and planning tasks for plant operators and the design of plant control systems [3]. MFM models represent plants in terms of goals, functions, and physical components. Based on the decomposition of a plant goal into sub-goals, sub-functions that achieve these sub-goals are specified in a functional decomposition. Sub-functions of the plant are represented as operations on flows and linked to physical components that implement them.

Functions in the FB are defined as operations carried out by a device on a flow. Functions of technical systems in MFM are defined as roles of components or systems in the achievement of goals [3] or as capabilities of systems [6]. Since both FB and MFM plant functions are realized by technical systems (in virtue of some facts or features specific to those systems) I take it that they correspond to physical capacities. Despite this common ground, the meaning of functional decomposition diverges between these methodologies.

Firstly, in the FB, operations on flows are modelled in accord with conservation laws for these flows, whereas this is not the case in the MFM (cf. [7]). Due to the FB modelling in accordance with conservation laws, some operations on flows are included in functional decompositions that do not clearly correspond to functional capacities. For instance, the operation-on-flow "dissipate acoustic energy" in a FB functional decomposition of a popcorn popper does not seem to contribute to the overall function of the popcorn popper to pop corn (cf. [8]), but seems included because energy may not be destroyed. In light of Cummins' criterion that, within an analytic explanation, the analyzing capacities are ascribed functions if they causally contribute to the analyzed capacity of the containing system, one can view the operation on flow "dissipate acoustic energy" as a mere capacity of the popcorn popper, not a functional one. In contrast, in MFM functional decompositions only capacities that are functional are included: only capacities that contribute to the achievement of goals are modelled, which do not have to accord with conservation laws. For instance, "source" functions in MFM represent capabilities of systems to create mass or energy by acting as infinite reservoirs of mass and energy, and "sink" functions in MFM represent capabilities of systems to destroy mass or energy by acting as infinite drains of mass and energy [6], violating conservation laws.

Secondly, in the FB, input flows constitute the precipitating conditions for operations carried out by technical systems on these flows as manifestations. In contrast, whereas operations on material and energy flows in MFM are carried out by technical systems, information flows in MFM constitute the precipitating conditions for operations carried out by plant operators on these flows as manifestations. For instance, the action of a plant operator of opening or closing a valve [3]. Thus, whereas sub-functions in the FB correspond to physical capacities of technical systems, sub-functions in the MFM can correspond to physical capacities of technical systems or capacities of agents qua user actions.

Thirdly, sub-functions in the FB always represent capacities of physical processes as transformations of material, energy, and signal flows. In contrast, sub-functions qua physical capacities in MFM either describe capacities of processes (realized by physical objects) or capacities of objects. For instance, a "source" function of a tank in a power plant that represents a coal or oil repository [3]. This function represents the storage capacity of a physical object and not a physical process qua transformation of a material flow.

3. RESULTS AND CONCLUSION

In sum, different senses of functional decomposition underlie the FB and MFM methodologies. The above analysis corroborates the view of Bucciarelli [4] that multiple conceptual perspectives on technical systems exist side by side in engineering. Whereas Bucciarelli analyses this diversity from a social actor perspective, I have approached this issue from an analytic perspective. The results also ground the views of Simons and Dement [5] on the multiplicity of part-whole relations of artefacts, suggesting a multiplicity of part-whole relations on the level of functions as well.

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METAPHYSICS OF ENGINEERING II

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The purpose of this essay is to extend the scope of previous work, namely, *Metaphysics of Engineering*.[1]

Like the previous work this paper rests on four main premises. First, like the learned works of all learned disciplines, learned works of engineering exhibit story elements: beginning, middle, ending; point of view; setting; and so on. Second, the beginning of an engineering work contains a sentence in the imperative mood which initiates the causative sequence in the plot or middle of the work. Third, an engineering work is said to be intellectual if this sequence obeys the rules of reason, and if the sequence is terminated by a sentence in the ending which is in the indicative mood, specifically, a justified true belief. Fourth, an engineering work may not be intellectual if its initiating command or request is sufficiently laden with constraints, and its plot is sufficiently fraught with exigencies, complexities and lethalities. And fifth, an engineering work is said to be practical if its plot is terminated by a sentence in the ending which is in the indicative mood but, albeit a true belief, is unjustified by reasoned argumentation and yet is said to be believable or worthy of commitment. This essay picks up where previous work left off. Previous work demonstrated that engineers have two ways of crafting practical engineering works.

One way is to craft its plot to obey the rules of reason except where overridden by the will to obey *ad hoc* rules called engineering heuristics. The heuristics theme characterizes learned works of engineering as metaphors of historical literature. For example, Turteltaub's *Justinian* can be compared with Gibbon's *Decline and Fall of the Roman Empire* as a work of engineering can be compared with a work of physics. When Gibbon talks about Justinian II he separates what is known from what is unknown and then moves on to tell a story worthy of being believed. When Turteltaub gets to unknown parts of Justinian's life he fills in the gaps with fictions: not merely entertaining fictions, but learned fictions which tell what might have happened or what could have happened. Turteltaub tells a story that is believable. Billy Koen calls the fictions in a learned work of engineering "heuristics." Accordingly, while a learned work of physics seeks belief, a learned work of engineering seeks believability. In the previous work the heuristics discussed consisted in Leibniz's *ad hoc* rules for manipulating infinitesimals and their applications to certain finite quantities called mesofinitesimals. Specifically, the algebraic equation

$$x_T = x + \Delta x$$

was discussed where: xT references the truth about a thing or phenomenon; x references knowledge about it; and Äx is a mesofinitesimal.

The other way of crafting a practical engineering work is to put its setting in a hyperreal world whose natural laws contain engineering heuristics, and to describe that world by means of a novel grammar that includes heuristics among its syntactics. Specifically:

$$\hat{x} = \langle x, \Delta x \rangle$$

replaces the above equation and is manipulated systematically.

Finally, pairs of learned works belonging to a class of learned works were produced: each work in a pair having the same beginnings and the same endings; but the middle of one is made the *ad hoc* way while the middle of the other is made the systematic way.

The first objective of this essay is to translate the grammar of the first way into the grammar of the second way, and *vice versa*. This is accomplished by theorem-1.

THEOREM-1: It is a simple matter to demonstrate that

$$\hat{f}(\hat{x}) = \langle f(x), f'(x)\Delta x \rangle$$

where: f' denotes the ordinary derivative.

The second objective of this essay is to consider pairs of learned works belonging to other classes. The theorems below can be applied to the problem of calculating, from data, the velocity of a mass using the apparatus represented as a schematic in Figure-1. This problem belongs to the class known as Newton's Second Law.

THEOREM-2A: the ordinary derivative of the first kind over ***E*** is as follows:

$$\frac{d}{dt} x(\hat{t}_n) = \langle \dot{x}(t_n), \ddot{x}(t_n)\Delta t_n \rangle$$

THEOREM-2B: the ordinary derivative of the second kind over ***E*** is as follows:

$$\frac{d}{dT} x(\hat{t}_n) = \langle \dot{x}(t_n), \ddot{x}(t_n)[\Delta t_n + \Delta T_n] \rangle$$

Two sets of data are possible: one with the clock running and the stopwatch disengaged; the other with both timers running. With the switch S in position 1, data is generated for computations of velocity using the ordinary derivative of the first kind. With the switch in position 2, the laser and clock steadily generate distance and time data, but now the stopwatch measures the time elapsed between successive reports from the clock. In this case, the ordinary derivative of the second kind is used to compute the velocity. We see that if the errors in the clock and stopwatch are negatively biased, i.e. Δ tn = -ΔTn , we conclude that the ordinary derivative of the second kind would render a more reliable computation than would the ordinary derivative of the first kind.

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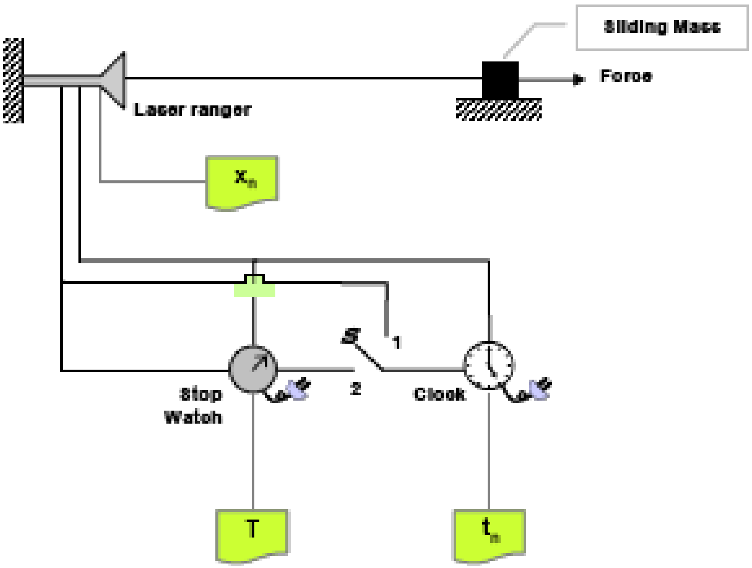

Figure-1

Ethical implications of ubiquitous computing

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Keywords

Ubiquitous Computing, Perception/Action, *Affordances,* Ethics, Ecological Philosophy.

1. INTRODUCTION

The main aim of this article is to investigate, from an interdisciplinary perspective, possible ethical implications of the dissemination of generalized sensors, cameras, amongst other technological tools, used by ubiquitous computing systems in human perception and action.

The contrast in approach to aspects of ubiquitous computing, between traditional considerations of ethical issues (Aristotle, Pascal, Kant, Bentham) on the one hand, and the Ecological Philosophy view (Gibson, Large) concerning its possible consequences in the context of perception/action on the other, is the underlying theme of the present paper.

2. UBIQUITOUS COMPUTING:ETHICAL ISSUES

In ubiquitous computing, the information processing power of computers is distributed everywhere in countless, intelligent, devices imperceptible to an inattentive observer. With the fall in prices of microprocessors, cameras and intelligent sensors, dissemination of ubiquitous computing continues to accelerate. Small passive tags help to detect the circulation of books and commodities in libraries or convenience stores. Intelligent badges can open doors or tollgates, adjust the room temperature of offices, help in the location of people, and operate various electronic devices, amongst other things. Although the collection of so much data concerning the lives and customs of people normally aims at the informatization of already existent manual processes, this information can be used for other purposes, including those which put personal privacy at risk.

The focus here is an analysis of how the generalized dissemination of microprocessors in embedded systems, commanded by an ubiquitous computing system, can affect the behavior of people considered as rational and autonomous agents. As new technological habits are incorporated into our social interactions, corresponding new moral conduct and ethics also adapt to these transformations. In earlier times, people treated privacy in many different ways. In certain situations, privacy was considered one of the most precious commodities, because it could guarantee freedom of political, professional or sexual choice. The right to privacy is an antidote against the danger of the State itself becoming a totalitarian power. However, in many situations, privacy can be either unwelcome or inappropriate. For example, Malinowsky argues that, independent of the importance of the symbolism of the ceremony of marriage, its essence resides in the necessity of making public a formal union.

At present, there is a strong tendency to make reality a spectacle of itself, stimulating an exhibitionist behavior of social or private actors/agents. To exit anonymity is associated with the concept of a successful career and, therefore, a step in the direction of personal recognition. A detailed register of the presence of individuals in specific places can be decisive for the elucidation of crimes. The ease of access and abundance of images registered by ubiquitous cameras can supply a rich material for the study of social customs, or for the sentimental recording of happy moments experienced by anonymous personalities.

In what way can the impact of ubiquitous computing on peoples' behavior be evaluated? According to the defenders of deontological ethics, duty, and not the consequence of an act, must govern the choices and decisions of a person. Kant [1] in his *Prolegomena to any future metaphysics*, argues that an observer, who saw a person running away, when interrogated by a bandit running in the direction taken by his victim, should not avoid the duty of always telling the truth. Utilitarian ethics [2], on the other hand, defends that "any action […] must be approved or rejected as a function of its tendency to augment or diminish the happiness of the party whose interest is in question". Thus, from an utilitarian perspective, the consequences of usages of ubiquitous computing should be investigated according to the following question: Would it augment or diminish the contentment of people involved with it? If the second alternative applies, then its use should be strictly regulated, and so on. In the same vein, Pascal [3] argues that actions should be performed in order to increase collective benefit: cooperative habits created by societies should attend fundamental needs, avoiding the worst of social consequences, such as civil war. Aristotle [4], in turn, argues that neither duty nor the consequences of collective habits, but "merits" should be the major guiding marker of ethics. Each person should act in accordance with his/her virtues.

An alternative approach to the problem of adequacy of utensils to human action is suggested by Ecological Philosophy (Gibson, 1986; Large, 2003). Ecological Philosophy, in contrast to Philosophy of Ecology, investigates the intrinsic natural relation between organism and environment in the context of perception/action. From this perspective, the impact of ubiquitous computing should be evaluated not in terms of its virtues or utilitarian consequences, but mainly in accordance with the dynamics of *affordances* available to organisms. *Affordances*, as defined by Gibson [5], constitute meaningful information specifying unambiguous (non-mediated) opportunities for action, and as such they can only be understood from a systemic perspective that conceives (potential) organisms in straight relation with the environment. Meaningful information, thus, is a relational property emerging from the system "environment-organism" [6].

The touchstone of Gibson's systemic view is the principle of *mutuality*, according to which organisms and environment co-evolve. He claims that each animal (including, of course, humans) has its own system of locomotion that constrains its relationships with other animals, plants and inorganic things, dynamically shaping its own surroundings. Even though locomotion is common to all animals, it varies amongst them in many ways, populating the environment with a rich diversity of *affordances* [5]. In this context, questions concerning possible consequences of ubiquitous computing may be reformulated as: what are the consequences of the dissemination of generalized sensors, cameras, amongst other technological tools, in human perception and action? In what way, in the long run, might they alter basic human habits developed from a straightforward systemic relation with the environment?

To illustrate the topic under discussion here, imagine a group of panda bears living in their natural environment. As vegetarian animals, panda bears have to grasp *affordances* related to various types of bamboos in order to survive. Differently from pandas, polar bears have to adapt their feeding habits grasping *affordances* related to a variety of meat. In both cases, ecological information provides *affordances* concerning the environment in which they live. Both groups are adapted to their surroundings thanks to *affordances* available in their niches, which allow them to act in order to survive even under very hard conditions. As these *affordances* do not exist in isolation, but constitute complex systems that constrain relationships with other animals, plants and so on, changes in some of their basic habits may produce great transformations in the dynamics shaping their own surroundings.

In the human context, the question to be analyzed here is: Could the generalized use of microprocessor, cameras and intelligent sensors widespread in our environment change drastically the *affordances* available to our every day routine? If so, what are the implications for the dynamics of our perception/action? These questions open up a new debate, which has not been addressed by traditional considerations of ethical issues on ubiquitous computing. One of the main contributions of this paper is to nourish this debate from an Ecological Philosophical perspective.

While in the classic, top-down normative ethic scheme the consequences of the adoption of ubiquitous computing may create ethic dilemmas with predominantly epistemological implications and consequent need of reformulation of some of its tenets, in the more bottom-up descriptive ethic behind the Ecological Philosophy, predominantly ontological implications are at issue underlying survival dilemmas.

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From Philosophy of Science to Philosophy of Engineering: The Case of AI

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1. INTRODUCTION

The interest in the interaction between philosophy and engineering has rapidly grown in the last years. Engineering, dealing with the exploitation of scientific knowledge for modeling concrete problems, seems to present several issues worth discussing from a philosophical point of view. Despite many valuable works, a detailed and systematic assessment of the field requires further attention, as it has been recognized from different parts (see for example [1]). A commonsense view considers the philosophy of engineering as an area of the philosophy of science, that part concerning in particular the applicative issues of science. This view lies on the idea that engineering is 'just' applied science. Accordingly, the philosophical problems of the philosophy of engineering would be 'just' the problems of analyzing the passage from theory to application, as if a clear-cut distinction between science and engineering should exist.

This talk is a contribution in the direction of a philosophy of engineering considered as partly autonomous from the philosophy of science. If, from the one side, the philosophy of engineering shares with the philosophy of science the goal to critically analyze scientific-technological problems, from the other side, the philosophy of engineering presents some interesting differences. I claim that these differences concern the types of problems analyzed and the method adopted to solve them. For this reason, the philosophy of engineering needs to be assessed partially independently from the philosophy of science.

The purpose of the talk is to present some distinctive features of the philosophy of engineering both at the level of problems and at the level of method. To argue in support of a peculiarity of the philosophy of engineering I discuss the case of Artificial Intelligence which has been defined as a science and as an engineering [2]. According to this definition, AI is both a science concerning the general study of intelligence and an engineering devoted to design concrete intelligent systems.

2. AI AS SCIENCE AND ENGINEERING

The case of AI offers good support to the idea of a philosophy of engineering distinct, under some respects, from the philosophy of science. From an historical point of view, there has always been a very strong connection between philosophy and AI. Some of the issues tackled by AI (e.g. the definition of intelligence, the nature of rationality, the boundaries of rational action,…) had been already discussed in the philosophical tradition. However, differently from what it seems at a first glance, the relation of AI with philosophy concerns not only AI seen as science, but also as engineering. In this sense, AI poses some of the traditional questions of philosophy in a new fashion. For example, how is it possible for a certain system, equipped with some specific features, to do X? Or in other words: how is it possible in general, and not only for human beings, X (where X can be perception, knowledge, or reasoning)? To answer such questions, AI adopts a peculiar approach which derives from its being an engineering. To check if X is possible, the AI way is to design a specific artificial system able to do X and, then, to analyze which of its features are essential in doing X [3].

In this sense AI is devoted to performance and its essential questions are posed in an engineering fashion rather than in a scientific one. This concretely means that, for example, the primary goal of AI is to build intelligent artifacts and then to study general intelligence by analyzing them. The target of AI as engineering is to meet the specifications required to solve the problems for designing intelligent systems, while the target of AI as science is to investigate if the systems that meet such specifications are really indicative of intelligence.

3. CONCRETE PROBLEMS AND EXPERIMENTAL METHOD

Keeping the engineering component of AI in mind, it is now possible to analyze more generally the problems and the method of the philosophy of engineering.

My first hypothesis concerns the focus of the philosophy of engineering. I claim that it focuses on very specific topics and not on general questions. To consider the AI example again, AI has the aim to design and build systems able to do X in the most efficient way. Particularly in the last years AI has lost interest in answering general questions about intelligence and has concentrated more on performances. This is also the reason why many answers to the critical questions (such as: how is it possible to do X?) sometimes have lost interest for the philosophers. The AI systems constituting the answers to these questions cannot be interpreted as particular cases of more general abstract systems, whose human cognitive processes are other possible implementations. They offer instead just specific answers which, most of the times, are difficult to generalize.

So, by considering AI as engineering one of the main issues becomes the efficiency of the artificial systems to be designed. Accordingly, the philosophical issues of AI change: they are not just general questions about the necessary and sufficient conditions to do X (both in human beings and artificial systems), but concrete analysis about the necessary and sufficient conditions for an artificial system to do X (where X in this case means something very specific, such as to realize an artificial agent able to participate in an electronic auction). It is worth noting that engineering does not exploit tools and technologies already ready for use. Nor it applies scientific theories directly to reality. Rather, engineering is a modeling activity, where the problem at hand must be 'seen' in terms of a scientific theory. Models, thus, represent the interface add an empirical component to epistemology. This way philosophy adopts the tools of computer modeling to support its ideas: it is possible to test an epistemological theory if the theory is realizable in a computer model [4]. In this sense AI systems may constitute a sort of test-bed for philosophical theories. Although the several limits of this approach, I deem verifiability in the philosophy of AI as an example of the kind of methodology that can be adopted in the philosophy of engineering.

If traditional philosophy of science exploits the tools of critical analysis, argumentation and, sometimes, formal logic, the philosophy of engineering can add experimental verification to these tools. Therefore, besides the traditional critical analysis of concepts deriving from the philosophy of science, the philosophy of engineering borrows verification as philosophical methodology from engineering. It is worth noting that verification needs not to be intended as in the old philosophical tradition of neopositivism, but in a new fashion. This way philosophical statements can be tried out by building concrete artifacts, such for example computers implementing computational model based on philosophical hypotheses that need to be tested, as the case of AI shows. Hence, from a methodological perspective, theories implemented as artifacts represent one of the distinctive traits of the philosophy of engineering.

In conclusion, philosophy of engineering, while sharing a great deal with the philosophy of science, also presents some peculiarities, which are worth stressing in the effort of a further assessment of the field. These peculiarities concern both the problems, which are related to the modeling activity typical of engineering and, thus, are more concrete than in the philosophy of science, and the method enriched by experimental verification.between theory, that speaks about abstract entities, and reality, composed of concrete objects. To apply a theory to reality, engineering needs to model these objects in terms of the theory.

The second hypothesis concerns the method of the philosophy of engineering that, under some respects, is different to that adopted by general philosophy of science. Again AI can help in illuminating this difference. One of the reasons of the interest of philosophers in AI has been the opportunity to have a framework to verify some general hypothesis. To be more concrete, AI (and in particular computationalism) seems to offer a scenario in which to analyze the mind-brain problem in a precise way. To verify the functioning of a given hypothesis about a cognitive process is sufficient to design a system implementing the hypothesis. Leaving aside the problem of the theory realization in a computer model (not surely why I consider it inessential or simply solvable), this approach has led to

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Whither Software Engineering?

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1. A BIT OF BACKGROUND

This paper began over a decade ago when I was teaching formal methods to prospective software engineers. Though the course was a core component of their chosen profession and all had successfully completed an undergraduate degree in a related field, their resistance to things theoretical was formidable. I began to wonder about the disparity between the intellectual preparations expected in traditional engineering versus those accepted in software engineering. Any beginning student of a traditional engineering discipline realizes that their first courses will be in mathematics and science — calculus and physics in particular. These foundational tools underlie the practical aspects of their future career. At best a software engineering student will begin with a similar program; but such topics are the stuff of software applications, not of the business of software *per se*. So I wondered when/how what we take as expected in traditional engineering education was introduced. And was it unrealistic to expect software to grow theoretical roots of a similar nature? That led to an examination the history of traditional engineering and its corresponding approaches to engineering education. Indeed Monte Calvert had given names to pre- and post- theoretical engineering education: the shop-culture and the school culture. This of course raised more questions.

2. PRE-CURSORS TO SCIENTIFIC ENGINEERING

It was clear that the direct precursor to scientific engineering was the fundamental work in mathematical physics by Newton and his intellectual descendants. But if there is to be a similar path from “shop” software to a discipline of software, then there has to be a different foundational mathematics — traditional engineering deals with continuous phenomena while software, at its heart, is discrete. Was there a common mathematical thread? There was: symbolic algebra. The operative languages for describing and reasoning about continuous and discrete phenomena are algebras of symbols. Symbolic algebra appeared on the scene in the late 16th century, with Francois Viete’s introduction of symbolic parameters to replace numeric coefficients. This allowed the description of *classes* of equations, and therefore the beginnings of a theory of equations. Viete realized that within these specifics a more general mechanism was concealed: the possibility to use symbolic manipulation to represent situations, to manipulate these representations, and then re-interpret the results as predictions that validly followed from the initial situations. He called this trio, Zetetics, Poristics, and Exegetics. This trio underlies our ability to replace experimentation with reasoning, and introduces the beginnings of representation and interpretation.

3. SCIENTIFIC ENGINEERING BEGINS

Two threads issue from these notions of symbol manipulation: first, continuous phenomena were symbolized within the differential and integral calculi, and science-based engineering followed. Later, algebraic properties of systems themselves led to modern algebra, to formal logic, and now — we claim — to mathematical foundations for software engineering

From the origins of symbolic algebra, through calculus and mathematical physics, the basic sciences that support modern engineering were developed. Those mathematical foundations for modern engineering, though a direct outgrowth of English work, took flower in France in the early 18th century. Why France? Why not England? And who in France had the foresight to recognize the long-term power of theory-based techniques? We argue that a distinction between Cartesian and Newtonian Enlightenment supplied the philosophical background that encouraged scientific engineering in France rather than the shop-based engineering championed in England and the United States.

Though France led the way, the French Revolution dampened the enthusiasm, and the English shop-culture approach won the commercial battle as well as setting the tone for American Engineering. Shadowing this progress, the educational establishment was struggling with how — or whether — to move the new theory into practice. We all know how that struggle turned out. Even though as late as 1920 the U.S. educational establishment was still debating the necessity for calculus in the engineering curriculum, England had adopted school-culture as its educational model by the mid-19th century and by the 1950s even the U.S. had followed suit.

Though theory-based engineering could be discounted as something of an intellectual conceit in the 18th century, electrical engineering and its separation from direct sensual experience placed more emphasis on underlying theory. A case-in-point is the transatlantic cable and the problem of locating failures far below the ocean’s surface. School-based theory made pin-point diagnosis possible where shop-based practice could only offer brute-force examination.

This competition between engineering philosophies in the 18th and 19th centuries is reminiscent of Kuhn’s notion of competing paradigms for scientific theories. Of necessity, as designs became more complex the school-based view held sway. As with many choices, things get lost. In this case issues that are directly addressable in a shop setting — like quality, responsibility, and ethical behavior — are ill-served in a lecture setting.

4. WHITHER SOFTWARE ENGINEERING

Given the history of engineering development and education, we argue that a similar pattern will occur in software development, not because of some academic whim but because the complexity of software demands that we expect higher standards. The critical problem in modern software is predictability: we need to know what to expect when we run a program or import software from the net. Such expectations are ill-served by current techniques. At best, programs are conjectures, free of justifications and supplied "as-is." In this day of the virus such a cavalier attitude is indefensible.

We're in a "pre-scientific" phase for software … a phase that emphasizes construction without theoretical justification. In traditional engineering, the physical world is the final arbiter of adequacy and mathematical physics supplies a theoretical justification for our conjectures. In software engineering, a program is the construction, a logical specification defines "reality," and a convincing argument that reconciles the construction with the specification must supply the justification.

But if one finds this argument convincing, then what kinds of mathematics can be offered for a "school-based" program in software engineering? What is needed is a different branch of symbolic algebra; one that allows the creation of software in conjunction with a specification of its properties.

Fortunately there are some mathematical foundations for software that show promise in addressing the interplay between program and specification. These techniques are the direct result of the work of 19th- and 20th-century philosophers and mathematicians. As with 17th century mathematical physics, symbolic algebras point the way. First Frege's Begriffsschrift supplied a language in which to analyze logical ideas. This technical breakthrough was followed by a philosophical one that refined the notion of truth. L. E. J. Brouwer rejected the classical view that truth is simply an assertion about a statement. In its place, he insisted that truth cannot be asserted without evidence; than an assertion is a statement combined with supporting evidence. A portion of these philosophical notions can be symbolized in a formal logic of evidence — Intuitionistic Logic.

These ideas were further developed into constructive logics, and from there it's a short jump to a mathematical foundation for typed programming languages wherein statements become expressions in a programming notation and evidence becomes a type. In many practical languages, the rules for combining these expression/evidence pairs are compositional, allowing us to decompose global requirements for complex programs into bite-sized assertions about individual constituents.

Currently, "school-based" programming suffers similarly to attempts at "school-based" engineering in the 18th-and 19th-centuries. Theory-based tools — both then and now — lack the sophistication and range that would convince many practitioners to adopt them. Recalling the impact of theory on the transatlantic cable, is there a software situation whose importance is recognized and whose solution eludes the current tools. Indeed there is; it's "software security."

5. PREDICTABLE SOFTWARE

Indeed, one should not even begin to discuss security in any meaningful way without a well-defined specification of what the software is to accomplish. That's the first half of the problem. In order to claim that a program meets a specification, a convincing argument must be presented. It's like mathematics: anyone can suggest a conjecture, but to qualify as a fact a convincing proof must be given. As things stand now, most programs — are at best — unsubstantiated conjectures.

Given programming notations whose constructs are based on the composition of type-theoretic components, we are beginning to see practical problems come within the grasp of theoretical techniques. A discipline of software engineering must proceed in two directions: increasing elaboration of the techniques to enlarge the domains of applicability; and an educational initiative must begin to replace the "shop-based" software education with an appreciation for theoretical tools.

In conclusion, there is reason to believe that (1) software construction will have to transform as physical construction did, not just for aesthetic/academic reasons, but because the complexity of the application will force the field's practitioners to design to predictable standards; (2) as differential and integral calculi supplied the requisite mathematics for predictability in physical construction, constructive type-theory offers a promising basis for software predictability; and (3) if history is any indicator, it will not be the educational establishments that lead the way.

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Engineering conceptual change: The Enactive Torch

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SUMMARY

In the Philosophy and Engineering community, there is general agreement that interaction between the two fields can be mutually beneficial. However, there are distinctive ways in which engineering can play a crucial role in assisting the particular case of philosophy of mind, especially concerning our understanding of conscious experience and perception. The reciprocal design/use cycle of certain kinds of experience-augmenting technologies can facilitate the kind of conceptual advance that is necessary for progress toward a scientific account of consciousness, a kind of advance that is not possible to induce, it is argued, through traditional discursive, rhetorical and argumentative means. We present an example of engineering activity that plays this crucial role in informing philosophical research in the PAICS group at the University of Sussex: the design and use of a novel sensory substitution device (the Enactive Torch) as a means of inducing in the user new philosophical concepts of perceptual experience.

1. THE NEED FOR ACTIVITY-BASED CONCEPTUAL CHANGE

Many of our problems in trying to understand consciousness are conceptual; the obstacles we face in understanding what it is for a physical thing to also be an experiencing thing are not just a matter of lacking empirical data. Even if we knew much more about the nervous system than we do now, some fundamental puzzling questions would remain. For example, on our current concept of consciousness, zombies seem possible. That is, it seems possible that there could be something that is physically (and thus behaviourally) identical to you and yet different from you with respect to its experiential properties, even to the point of not having any experiences at all: a zombie-you. Such a possibility poses serious difficulties for a naturalistic, scientific account of consciousness (cf, e.g., Chalmers 1996).

One way of responding to this is to diagnose the difficulty as the result of flaws in our concept of consciousness. If our concept of consciousness has near-paradoxical implications, perhaps we should try to develop a new concept of consciousness that does not (cf, e.g., Nagel 1980). But it seems unlikely that the kind of conceptual change required can itself come about solely through conceptual processes alone, such as adding propositions to, or subtracting propositions from, one's stock of beliefs (whether it be by learning some more facts about consciousness or about the brain, or by engaging in philosophical arguments), or creating a new concept out of logical combinations of the concepts one already possesses. Rather, such changes might require the philosopher concerned to undergo certain kinds of experience, those that result from engaging in certain forms of activity. If being able to shift from seeing an object one way to seeing it another way is the "mastery of a technique" (Wittgenstein 1972, p 208), or a skill, then perhaps, too, being able to shift from understanding consciousness in our current inchoate way to another way that is less paradoxical and problematic, can itself be seen as requiring the possession of a skill.

And skills, notoriously, cannot be transmitted merely linguistically or through argumentation; typically, they require engaging in a particular form of activity. Perhaps, then, the kinds of conceptual advance we require for better philosophical concepts of consciousness require the philosopher to experience active engagement with consciousness-related phenomena in some way. This position is called "interactive empiricism" (Chrisley 2008a, Chrisley 2008b).

Another way of making the point is this. A general science of human cognition should apply to individual cognizers; specifically, it should apply to cognitive scientists, philosophers, and engineers. If cognitive science is telling us that cognition in general, and conceptual development in particular, is crucially interactive, then it may also be that making philosophical advances via conceptual development will necessarily involve engaged, experiential activity.

2. AN ENGINEERING SOLUTIONS: THE ENACTIVE TORCH

The Enactive Torch (see figure 1) was designed by Froese and Spiers (2007) as a tool to aid the philosophical and scientific investigation of perception. It was inspired by the observation that while there is much debate concerning, e.g., the phenomenology of using sensory substitution devices, so far no agreement could be reached on how best to characterize that phenomenology, and that this was likely due to the fact that the philosophers participating in the debate had apparently never tried out these devices for themselves. Thus, of special concern for the design of the Enactive Torch was the notion that the device should be very accessible for first-person use. More precisely, this meant that it had to be cheap, non-intrusive and easy to build such that it has the potential of becoming widely distributed to the research community, as well as being simple enough to use such that it did not require hours of training but still generated interesting insights.

The Enactive Torch fulfils these requirements as a simple distal-to-tactile sensory substitution device that translates the distance measures of one ultrasonic sensor to a single tactile (rotary or vibratory) output to the hand. Below we elaborate more fully on why the device was engineered in this manner.

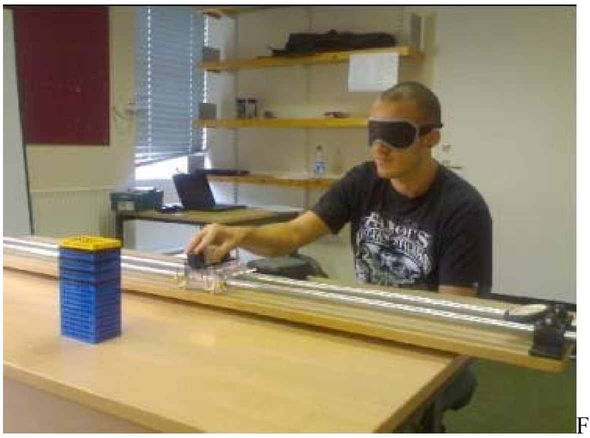

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Figure 1. Previous page: The Enactive Torch Mark 2 (ET2). Above: Constrained movement experiment using ET2.
Images from http://enactivetorch.wordpress.com/

2.1 Depth Information

Since color perception is one of the key properties of the visual modality, it is not surprising that most visual-to-tactile sensory substitution systems are designed to translate color information ofthe environment (i.e. in the form of a black and white or gray scale image) to tactile stimulation of the body (i.e. an array of vibrators on the stomach or tongue). However, completely reducing vision to the perception of colour leads to an impoverished characterization of the function and phenomenology of the visual modality. The perception of depth (and space in general) is arguably just as important. Indeed, in terms of an evolutionary perspective it could be said that it is more essential to perceive how far away a predator is compared to one's current location rather than whether it happens to be blue or white. The importance of depth perception through the visual modality for our everyday lives is exemplified by the fact that the blind can do well without perceiving colour but generally do have to rely on a cane (which provides a sense of distance to surrounding objects) to find their way around the environment.

2.2 Tactile Output

It has been argued by Auvray and Myin (submitted) that sensory substitution devices using tactile output are faced with certain limitations (i) because they depend on the stimulation of a highly sensitive skin surface such as the tongue leading to problems of skin irritation or pain, and, following Lenay and colleagues (2003), (ii) because the portability of such devices is constrained due to the substantive energy consumption of the tactile stimulators. The Enactive Torch avoids both of these limitations since it only makes use of a single tactile output. This means that (i) it can make use of the special sensitivity of the hand without becoming intrusive, and (ii) has very little energetic requirements; these are incorporated into the device in the form of standard batteries. Moreover, the simplicity of the single distal-to-tactile transduction process makes a connection to a PC unnecessary, thereby further increasing portability. The Enactive Torch therefore matches the advantages sometimes conferred upon visual-to-auditory substitution devices (Auvray & Myin submitted), but has the added advantage of limiting the intrusiveness of the interface, which is especially true considering how important the auditory modality is for the blind. Indeed, in contrast to most sensory substitution devices, the Enactive Torch combines the input and output interface into one (handheld) component.

2.3 Limited Bandwidth

The main philosophical objection to the Enactive Torch could be its simplicity. Surely, with the limited capacity of only one dimension of input and one dimension of output, the perceptual ability the device affords must be extremely limited? However, when philosophers question the engineering choices in this manner they are implicitly basing their argument on the premise that channel capacity determines perceptual resolution. Already a limited amount of exploratory use of the Enactive Torch makes it clear that this premise is not necessarily valid. Indeed, it turns out that, similar to the eye saccades that constitute visual perception, through active exploration with the device it is possible to generate a felt presence of the surrounding environment that transcends the direct physical stimulation of the hand. Moreover, it becomes evident that our nervous system is highly adapted to picking out significant sensorimotor correlations from a background of noise, since the occasional hardware glitches (i.e. false stimulations) are easily cancelled out by further exploration. Attention then shifts from the initial focus on the perturbation of the hand, to the contours of objects that appear in experience as present in the distant environment. The importance of embodied action for the constitution of perceptual objects thereby becomes accessible to direct experience, as the sensations from a device that is not used for active exploration are meaningless to the subject. The Enactive Torch is therefore a demonstration of how engineering can produce devices that, through their use, can induce changes in one's concept of perceptual experience.

3. DISCUSSION

It is proposed that a philosopher's experience of interacting with devices like the Enactive Torch can play a critical role in the development of their concepts of experience. This role takes the form of two reciprocal loops. The first is the *use loop*, and is constituted by a philosopher's experience of interacting with the world using the Enactive Torch, reflection on such experiences, incremental or non-conceptual alteration of their concepts, and modulation of interactive modes as a result of these non-conceptual and conceptual developments. The second is the design loop, available only to a philosopher that plays a role in the design of the device. This loop is constituted by a interaction between experiences (both one's own and others') of using the device, changes in concepts involved in engineering/designing the device, changes in the actual design of the device, and the resulting impact such changes have on the experiences one has with the device. Of course, these two loops are not independent.

It should be stressed that the role of such experiences is not the same as the role of say, experimental observation in standard views of empirical science. On the orthodox view, an experiment is designed to test a (propositionally stated) hypothesis. The experiences that constitute the observational component of the experiment relate in a pre-determined, conceptually well-defined way to the hypothesis being tested. This is strikingly different from the role of experience emphasized by interactive empiricism, in which the experiences transform the conceptual repertoire of the philosopher, rather that merely providing evidence for or against a proposition composed of previously possessed concepts.

4. FUTURE WORK

Two methods of evaluation are being considered to test the effectiveness of the device with respect to the goals of interactive empiricism and conceptual change: first person phenomenological methods, and third person methods from the relatively new field of experimental philosophy.

Initial steps for the first method have been taken undertaken recently by Petitmengin, who applied her interview techniques for eliciting detailed phenomenological descriptions (Petitmengin 2006) to a subject (Froese) who used the Enactive Torch in order to explore and attempt to recognize an object while blindfolded. The next step in this method is the development of techniques for analyzing the resulting transcripts so that cross-subject generalizations can be made. Other possible first person techniques that may be of use here include the Descriptive Experience Sampling Method (Hurlburt and Heavey 2006).

Experimental philosophy (Nichols 2004) looks at the way in which subjects' philosophical views (usually conceived as something like degree of belief in a proposition) change as various contingencies related to the proposition change (e.g., how does the way one describes an ethical dilemma change subjects' morality judgements of the various actions in that situation?; cf, e.g. Knobe 2005). One could apply this technique directly, by empirically investigating how use of the Enactive Torch affects subjects' degree of belief in propositions concerning the nature of perceptual experience. However, it would be more in keeping with the insights of interactive empiricism if such experiments measured behaviour other than verbal assent to or dissent from propositions, such as reaction times and errors in classification behaviour. This might allow one to detect changes in subjects' conceptions of the domain that are not reportable or detectable by more propositional, self-reflective means.

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Dual Responsibilities: Balancing Employee and Engineering Considerations in Engineers' Decision-Making

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This paper forms part of a larger project to establish a new model for engineering ethics in a global corporate environment. In a previous paper I argued that engineering obligations for the 21st Century must be developed independently of particular national traditions and in the absence of the use of Western moral theory. This led to the development of a number of fundamental ethical principles for engineers (WPE 1 papers, forthcoming). However, these principles were intended to have a limited normative character, functioning as *prima facie* duties, since they only applied to engineers *qua* engineers. In this paper I add the additional recognition that the great majority of engineers are employed by private corporations which also exercise legitimate moral demands on the actions of engineers which must be adjudicated. A final paper will locate engineers' responsibilities in the complexity of a global landscape fraught with a variety of differing cultural conditions.

Current discussions in engineering ethics appear to be dominated by two perspectives regarding the role of engineers as employees. One, the more typical one, derives from the historical quest for professionalism. In this perspective the autonomy of engineers is emphasized, leading to an ignoring or complete overriding of other moral duties which might apply in a particular circumstance. In their professional capacity engineers are to exercise only their responsibilities as engineers. This perspective can lead to the counterintuitive result that minor engineering obligations can be given more weight than major ethical demands arising from other sources. The deficiency in this perspective is recognized by the introduction of family and employee responsibilities in more complete discussions of engineering ethics. However, these are typically introduced without any guidance for resolving potential conflicts among the variety of duties, but with the unstated traditional underlying premise that engineering duties should be given priority, with other considerations serving mainly as excusing conditions for violation of engineering ethical principles.

In this paper I begin with a discussion of the variety of role responsibilities we have as human being, of which engineering responsibilities might be one subset, but one which does not automatically have paramount status. Since the particular focus in this paper is on the employee status of engineers, a set of ethical principles for supervisory and other employees is then developed without the utilizing moral theory, as in my prior paper, but instead based on the role of business in a market system. Justifications for such an approach are provided. The resulting principles are listed below. One list expresses principles relevant to engineers acting as agents of corporations (managers); the other applies to all engineers, including managers, working for corporations. The lists themselves are not particularly controversial or unusual. They are not intended to be. What makes them significant is the way in which they are derived in a fashion similar to my referenced earlier paper and their role in engineering decision-making.

Principles for Corporate Managers:

Managers should endeavor to
1. Avoid producing unnecessary harm to people inside and outside the organization through corporate actions.
2. Ensure that all stakeholders of the organization are treated fairly and justly.
3. Ensure that all applicable ethical laws and regulations are followed within the organization.
4. Protect members of the organization against internal discrimination and harassment.
5. Make all hiring, compensation, promotion, and firing decisions based on merit.
6. Ensure that all legitimate corporate contracts are upheld.

Principles for Employees:

Corporate employees should endeavor to:
1. Obey all legitimate, job-related directives.
2. Perform their contracted duties on at least an industry-standard level.
3. Uphold the principle of confidentiality in relation to knowledge gained at a present or past employer.
4. Avoid actions which harm the corporation while acting on behalf of the organization.
5. Be honest in their business relationships with others.

The final part of the paper then discusses guidelines for resolving potential conflicts between employee duties and engineering duties in circumstances when neither is given *a priori* priority. The conversion of prima facie duties to actual duties is based on the understanding of role responsibilities, as well as on the application of the principles of nonmaleficence, beneficence, and justice. The approach stresses the need for consideration of individual circumstances and thus advocates the importance of dealing with case studies in deliberations regarding engineering ethics. It is also recognized that he development of the above schema has implications for contemporary discussions of whistle blowing in engineering. The primary emphasis, however, is on establishing that engineering obligations do not have an absolute character.

Being in Control
Towards a Model of Rational Acceptance of Technology

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Technology acceptance, use-plan analysis, rationality, control, philosophy of technology, cognitive psychology

1. INTRODUCTION

Control is an indispensable notion in reflecting on technology, from various perspectives. On a 'micro'-level, if technology is regarded as a means of controlling the environment, engineering is all about control. In addition, control engineering aims at controlling artificial systems. On a 'macro'-level, philosophers of technology reflect on the (im)possibility of controlling the process of technological change. And on what may be called a 'meso'-level, control over technical artefacts is pivotal in thinking about the interaction between designers and users. Not only is there a need for designers to transfer a measure of control over artefacts to users in introducing technologies (Pols 2008), lack of (perceived) control over new technologies might deter intended users or even make them hostile towards those technologies (Baronas and Louis 1988).

In this paper, we focus on the meso-level. We seek to improve our understanding of how users come to accept new technologies and how designers may influence this acceptance. For this purpose, we combine two strands of research: one in the psychology of technology acceptance, the other in the analytical philosophy of technology. This combination focuses on the notions of 'control' and 'use plan'. It results in a schematic model of Rational Acceptance of Technology that repairs some of the shortcomings in psychological models, in particular their normative implications and their implications for the design of new user technologies. Throughout, we illustrate our claims by drawing from the emerging field of 'persuasive technology', i.e., (information) technology designed to motivate and influence users to adopt a certain attitude or behaviour (Fogg 2002; De Kort et al. 2008).

2. TAM TO UTAUT

In cognitive social psychology, there is a tradition of developing models of user acceptance of information systems, starting in the late 1980's (Davis, Bagozzi and Warshaw 1989). The core of this Technology Acceptance Model, grafted on general theories of behavioural change (e.g., Ajzen and Fishbein 1980) is the identification of several beliefs and attitudes that together determine the intention to use a technology, which in turn determines actual usage. Later developments of the model retain the focus on information systems and show a careful, empirically informed pruning of relevant beliefs and attitudes. In intermediate versions (e.g., Taylor and Todd 1995), 'perceived behavioural control' and 'controllability' were introduced to capture beliefs about personal control over technology as well as organizational support of usage. However, in the most recent and empirically most encompassing model, the Unified Theory of Acceptance and Use of Technology (UTAUT; Venkatesh et al. 2003), these control-oriented constructs have been abolished in favour of the less specific 'facilitating conditions'.

3. LEAKS IN UTAUT

Despite its empirical success and conceptual sophistication, UTAUT still has several shortcomings and hiatuses. Among these, the model's inabilities to capture the way in which user attitudes towards technologies typically change, and to capture the relations between individual attitudes and social norms have been discussed in the literature. From our perspective, we can add three more hiatuses. Firstly, UTAUT and virtually all its predecessors black-box the design process: information systems are treated as fixed, finished products, and users interact exclusively with these systems, not with their designers. As such, psychological theories of technology acceptance address managers who supervise the implementation of information systems in large organizations – leaving the implications for designers unexplored. Secondly, UTAUT is presented as describing actual technology acceptance by users. Yet its emphasis on beliefs and intentions conceal evaluative aspects, if only because intentions based on false beliefs may be discredited as irrational. Finally, perceptions of control have been identified as important in the acceptance of new technology, but have no place in UTAUT. This phenomenological shortcoming is also evaluatively significant, since measures of control over artefact use have direct implications for responsibility, e.g., for misuse of the artefact. User intuitions regarding the relation between control and responsibility play a minor role in some questionnaires that provide data for psychological models, but have not been systematically explored, and the relation is not conceptualized in the models.

4. USE PLANS

Recent developments in the analytical philosophy of technology offer an opportunity for amending those shortcomings and clarifying psychological models of user acceptance. In the use-plan analysis of artefact use and design (Houkes et al. 2002; Houkes and Vermaas 2004), an explicitly evaluative model is presented for the interaction between designers and users. This interaction is mediated by use plans, i.e., goal-directed series of considered actions, including manipulation of one or more artefacts. Standards of rationality may be applied to use plans and, through them, to use and design. Moreover, by communicating use plans, designers transfer to users certain forms of control over artefacts and responsibility for artefact use (Pols 2008).

5. RATIONAL ACCEPTANCE

In combination, UTAUT and the use-plan analysis model the rational acceptance of technology by users, and incorporate a rich notion of control. The resulting RAT-model stays inside the belief-intention-action framework of cognitive social psychology. It does, however, lead to several modifications with respect to UTAUT. It suggests that intentions-to-use are to be understood against the background of executing use plans. These plans are communicated to users by designers, and are supported by beliefs about, among other things, the skills of the user, the capacities of the used system, and the availability of auxiliary items.

These beliefs partly reflect UTAUT's central concepts of performance expectancy and effort expectancy – meaning that RAT is empirically equivalent to UTAUT with respect to these determining factors, but more parsimonious in the way that it connects the beliefs to one central concept. In addition, RAT incorporates the phenomenologically relevant beliefs about personal control, through the transferred use plan, and it explicates the concept of 'facilitating conditions' in terms of circumstances that are known to be beyond immediate personal control, such as organizational support.

The combination is explicitly evaluative as soon as one requires the supporting beliefs to be *justified* and one enforces a principled, but straightforward distinction between constructs that appeal to user perceptions (e.g., perceived ease of use) and constructs that appeal to actual features of usage (e.g., actual ease of use). Furthermore, rational acceptance of technology requires the user to accept under certain circumstances the responsibility for failed use – a requirement that is an integral part of our proposed model, but conspicuously absent in present psychological models.

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Have we just moved into the age of technoscience?

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ABSTRACT

Some philosophers strongly demarcate the natural from the engineering sciences and, more generally, science from technology. Others agree that the natural and the engineering sciences and science and technology may overlap in certain respects, but still claim that they can and should be empirically and/or conceptually distinguished. Recently, however, both the more radical and the more moderate claims about the distinctions between technology, the engineering sciences and the natural sciences have been challenged by several authors.

In an extensive historical paper, Paul Forman argues that since about the 1980s there has been an 'epochal change' in our views of the relationship between science and technology (Forman 2007). Since that time, science has come to be seen as subordinated to technology, both as regards its role in actual practices and as regards its rank in socio-cultural evaluations. In a similar vein, Alfred Nordmann proposes the claim that, roughly in the same period, there has been an 'epochal break' in the historical development of science, from a scientific to a technoscientific enterprise (Nordmann 2009). Related, but somewhat broader, are the views that there has been a fundamental change from a Mode 1 to a Mode 2 approach to the production of scientific knowledge (Gibbons et al. 1994) or from an academic to a post-academic or industrial science (Ziman 2000). These views deny, or strongly question, any basic distinction between present-day natural and engineering science or between science and technology.

In this paper (see Radder 2009), I discuss and evaluate these views, with a focus on the 'epochal break thesis' put forward primarily by Nordmann and Forman. The epochal break thesis constitutes a bold claim with historical, philosophical, social and moral dimensions. The paper addresses some aspects of each of these dimensions.

First, I argue that the idea of a single 'great divide' between a scientific and a technoscientific enterprise is questionable on both historical and philosophical grounds. Yet, this does not imply that there are no important distinctions at all between recent and past science. In section II, I point to two novel nonlocal patterns, both related to an increased significance of engineering science and technology: first, a strong focus on the issue of the external validity of scientific methods and claims and, second, a substantial commodification of academic research. In section III, I conclude that a conception of scientific development in terms of the emergence of novel nonlocal patterns is preferable to an account in terms of an epochal break. Furthermore, I elucidate how nonlocal patterns may be identified and explained and what is implied, and what not, in postulating the existence of such patterns. Using Max Weber's notion of ideal-typical explanation, the paper closes with an argument for making explicit the normative issues involved in advocating philosophical claims, be they about epochal breaks or about novel nonlocal patterns. In my case, this implies to highlight, scrutinize, explain and assess the implications of the commodification of academic research.

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Artes Liberales and Ethics for Engineers

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1. INTRODUCTION

"Philosopher or engineer?" So read a question appearing in an article on the nature of the liberal arts in an alumni publication from Williams College. Not surprisingly, given the article's source, it defended the case that undergraduates should choose the former over the latter, quoting as follows from a Williams faculty member:

> I once asked the personnel director for a major aerospace company what kind of student he is most eager to recruit. 'I'll always go for the philosophy major,' the personnel director said. 'They know nothing about aerospace, but they know everything about complexity — and that's what I need.' [1]

Among the key themes struck by WPE 2007 that will be struck again in this year's workshop, was the call to reform engineering education by increasing the capacity of engineering students to think more critically, more imaginatively, more expansively, with greater social and historical awareness, and an increased capacity for and comfort for dealing with ambiguity in meeting challenges in the design process. Integrating more of the tradition of liberal arts education into engineering education would I agree be all to the good. At the same time, I would like to suggest that reforming engineering education goes beyond drawing "thinking like an engineer" [2] into a closer relationship with "thinking like a philosopher." There are ways that philosophy education could change as well for the benefit of future engineers (not to mention other students), particularly with respect to the design of the typical ethics curriculum within philosophy. In this paper I reflect on one way that that curriculum could be changed. That way has do with making more room in ethics curricula for the teaching of particular skills.

2. TEACHING UNDERGRADUATE ETHICS AND THE LIBERAL ARTS (1)—A TIGHT AFFINITY

The tradition of the liberal arts is grounded in the teaching of skills. The original aim of the study of grammar, rhetoric, dialectic and other subjects of the *artes liberales* was to build the skills essential for thinking as a free human being. This aim is arguably most clearly reflected in today's philosophy curriculum in the important place that curriculum gives to teaching the skills of critical thinking, a place not confined to courses given that special label but spread across the philosophy curriculum itself. We can see this emphasis play out in the design of basic ethics courses as students are taught to develop a capacity for analyzing ethical arguments and problems, and for applying what they learn in new situations—the "making and breaking" of arguments central to the activity of critical thinking. And, as individual capacity for "making and breaking" arguments increases, so hopefully does the respect for ethical positions not one's own. Respect for positions with which one disagrees is another "staple" outcome of a liberal education for the demands of the 21st century as articulated perhaps best in the writings of Martha Nussbaum. [2]

3. TEACHING UNDERGRADUATE ETHICS AND THE LIBERAL ARTS (2)—AN UNEASY RELATIONSHIP

Outside of the skill of critical thinking (and its curricular cousins of writing/composition, oral communication, and the like.), philosophy-based ethics courses tend by and large not to be oriented toward the acquisition of skills; the more advanced ethics courses are in the philosophy curriculum, the more they deal with disciplinary content rather than sharpening skills. In particular, ethics courses tend to shy away from focusing on developing the creative capacity for (a) seeing ethical problems to begin with—how they organically arise, for example, out of individual relationships to technological objects and systems--and for (b) making good judgments and decisions about these problems in a fluid, evolving world of imperfect information.

One reason for the relative absence of focus on cultivating the capacity for these skills has to do with the heavy lifting that basic ethics courses already have to do; namely, to serve as an introduction to the disciplinary subject matter of ethics itself: primarily normative ethical theory, metaethics, and applied ethics. But another and arguably more important reason why these skills are downplayed may be that they fall closer than do critical thinking skills to the line where teaching ethics shades over into moral education, where "reasoning better" shades into "being a better person."

I would like though to suggest that no matter what view one happens to hold regarding the character of engineering as a profession, approaching the teaching of ethics with the development of these skills in mind would benefit engineering students as future practioners whose work as Bucciarelli puts it unfolds in the "ecological" ebb and flow of the design setting. [4] In some sense, this suggestion is akin to the one made by Tim Healy that it would be beneficial for philosophers to ease up on relying on teaching ethics by presenting artificial dilemmas in the classroom (just as engineers should also realize the limitations of relying on thin models in the same setting). It differs, though, in that for Healy the onus falls on philosophers to present more true-to-life situations, whereas I am suggesting that this is a challenge with which students ought to be tasked themselves.

4. IN CONCLUSION, A QUESTION

In teaching ethics to engineering students, why else might it be pedagogically desirable to focus not only on taking arguments apart and putting them together in the context of already-defined issue and problems, but also on teasing out and identifying ethical problems from these students' own lived experience—and in particular, from their own lived experience with technology?

I'll work through an example or two in exploring the idea that among the advantages such a starting point might offer are the expansion of attentiveness and natural curiosity, as well as the growth of the skills of discernment and differentiation. By the latter I have in mind being able to distinguish what genuinely matters in a situation from what is less relevant or completely unimportant; and being able to see elements of a particular situation as demanding of ethical attention even though the problem at hand escapes familiar labels (eg conflict of interest) These are all good skills for anyone to develop, but particularly so for engineering students in our times.

It could be said that the particular intellectual skills I want to talk about in my paper are "back room" characteristics of a liberal arts education: they are rarely the focus of prime time in the classroom and one would be hard pressed to find them on a typical list of liberal arts student learning outcomes. Arguably, however, the more students' lives become embedded in infomedia technologies, the more their capacity for effectively exercising these kinds of skills is put at some risk. Ortega y Gassett once said that the basic metaphysical orientation of human life is to be "caught up in situations not of one's own making." [6] The same could be said regarding the basic orientation of the engineering design context. For philosophers to give more instructional recognition of the above skills would not only help engineering students in developing more context-sensitivity, but would also help in expanding recognition that the *artes liberales* for the 21st century must be first and foremost the *artes liberales* for a technological age.

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Promoting a Culture of Peace *within* Engineering – Engineering *for* the Promotion of a *Culture of Peace*

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conflict, MacIntyre, peace, practice, security, strategy.

1. INTRODUCTION

In a world of limited resources, limited sympathy and limited rationality, competition leading to tensions and conflict can arise. In such circumstances, a key responsibility of any society is to ensure the security of its citizens. The role of engineering in contributing to such security is most usually considered to be the development, manufacture and use of military equipment so as to ensure success if tensions result in violence. War is the normal business of engineering.

To make a contribution to international security is a worthy goal for individual engineers and engineering enterprises. However, contributing by preparation for war is an inadequate response, especially considering recent analyses of the origins of conflict, government policy and international initiatives. In seeking to identify more effective alternatives, this paper firstly summarises an approach to the overall ethical nature of engineering. Secondly, recent analyses of the origins of conflict are outlined. Thirdly, the incorporation of such analyses in government strategy is identified. Fourthly, the role for engineering in the major UN *Culture of Peace* initiative is made explicit.

The paper aims to contribute to a reprioritisation of the use of engineering by encouraging engineers to reflect on how they can best use their skills in the pursuit of peace.

2. THE OVERALL ETHICAL NATURE OF ENGINEERING

The overall ethical nature of engineering may be clarified by considering it as a *practice*, “a coherent and complex form of socially established activity”, of the type most extensively elucidated by MacIntyre [1][2]. The UK Royal Academy of Engineering has provided a cogent and challenging description of what might be considered *the practice of engineering:*

> Professional engineers work to enhance the welfare, health and safety of all whilst paying due regard to the environment and the sustainability of resources. They have made personal and professional commitments to enhance the wellbeing of society through the exploitation of knowledge and the management of creative teams [3].

Practices have a number of key features, including *internal goods*, *external goods* and *ends*. The *internal goods* of engineering are in particular those associated with the accurate and rigorous application of scientific knowledge combined with imagination, reason, judgement and experience. The *external goods* of engineering include considerable economic benefits to society, but particularly technological artefacts. The *end* of engineering may be described as the promotion of human flourishing through contribution to material wellbeing. The success of a practice is facilitated by human *virtues*, and those particularly necessary in the case of engineering are: accuracy and rigour; honesty and integrity; respect for life, law and the public good; and responsible leadership – listening and informing [2][3].

Several features of such a practice of engineering are especially relevant in the present context. Firstly, the practice is defined as being concerned with the welfare, health and safety of *all,* an aspiration extending beyond the boundaries of nation states. This is a very demanding aspiration, which in many situations may be impossible to fulfill. However, the design, manufacture and use of the many modern weapons of indiscriminate effect and huge devastation power appears overwhelmingly to be outside the scope of such a practice. Secondly, many engineers work in the military industries because of the opportunities to develop devices of great technical ingenuity. However, when engineering is considered as a practice, technological artefacts are only contingent products, external goods, in the pursuit of human flourishing. The prioritisation of technical ingenuity of a type designed to cause great human suffering is a very perverse approach to engineering.

Nevertheless, concern for the welfare, health and safety of all should naturally include consideration of actions that promote international peace. Here a further feature of a practice, that its goods and ends should be *systematically extended,* is important. The following sections will consider how recent analyses of the origins of conflict, government strategy and international initiatives suggest a reprioritisation and extension of the role of engineering in the pursuit of peace.

3. THE ORIGINS OF CONFLICT AND APPROACHES TO PEACE

Independent organisations such as the Oxford Research Group have provided perceptive analyses of current threats to peace and of the most effective responses [4]. The Group identifies four factors as the root causes of conflict and insecurity: climate change, competition over resources, marginalisation of the majority world and global militarisation. The Group characterises the predominant current responses as a *control paradigm* - an attempt to maintain the existing state of affairs through military means. They propose that a more effective approach is a *sustainable security paradigm* - to cooperatively resolve the root causes of these threats using the most effective means available.

It will be noted that engineers can play a major role in resolving each of the four root causes identified. For example, development of renewable energy sources can reduce climate change; improved efficiency and recycling can reduce resource competition; generation of wealth can diminish marginalisation; and reducing or halting weapons development can limit militarisation.

4. UK GOVERNMENT STRATEGY

Despite the modest size of its population and its peaceful geographical location, the UK has the second highest military budget in the world in cash terms, and the fifth highest in purchasing power (after the US, China, India and Russia). UK government strategy on security therefore has global significance, and it has recently been clarified in a single document for the first time [5]. This publication makes clear that "The broad scope of this strategy also reflects our commitment to focus on the underlying drivers of security and insecurity, rather than just immediate threats and risks". It further recognises that climate change, competition for energy and water stress are "the biggest potential drivers of the breakdown of the rules-based international system and the re-emergence of major inter-state conflict, as well as increasing regional tensions and instability".

The consonance of these aspects of the strategy with the Oxford Research Group's analysis is striking, and the challenge to engineers is again clear. The UK government has also created an initiative specifically "to help manage conflict and stop it spilling over into violence...Preventing conflict is better and more cost effective than resolving it" [6]. However, though this strategy and initiative are very welcome, there is at present a tentativeness about their implementation. Thus, the total UK budget for conflict prevention and peacekeeping is only about 2% of that for direct military expenditure, and of the same order as subsidies to arms exporters [7].

5. A CULTURE OF PEACE

Absence of conflict is a necessary but not sufficient condition for sustainable peace. Peace is additionally characterised by relationships between individuals, and social groupings of all sizes, based on honesty, fairness, openness and goodwill. Thus, peace requires more than engineering, it also depends on a multitude of cultural, societal and political factors. Hence, if engineering is to contribute fully to the pursuit of peace it needs to align its activities with those of other like-minded individuals and institutions.

Alignment of engineering aspirations with the United Nations initiative which began with a *Declaration and Programme of Action on a Culture of Peace* [8] may be an especially effective way forward. Such a culture is considered to consist of values, attitudes and actions that promote cooperation and mutuality among individuals, groups and nations. The United Nations has identified eight action areas [9]: fostering a culture of peace through education; promoting sustainable economic and social development; promoting respect for human rights; ensuring equality between men and woman; fostering democratic participation; advancing understanding, tolerance and solidarity; supporting participatory communication and the free flow of information and knowledge; and promoting international peace and security.

Some of these action areas can show immediately recognisable benefit from engineering, such as the promotion of sustainable economic and social development. However, all the action areas, even those that first appear purely societal, can benefit from appropriate engineering. For example, provision for effective distribution of information can foster participatory democracy, and drilling convenient wells can promote gender equality as women are freed from the often onerous task of collecting water from a remote source.

6. PROMOTING A CULTURE OF PEACE *WITHIN* ENGINEERING – ENGINEERING *FOR* THE PROMOTION OF A *CULTURE OF PEACE*

In the past, engineers have too often prioritised the production of ingenious technological artefacts rather than genuinely promoting human flourishing. Hence, the task of contributing to security through resolving the root causes of conflict first requires the promotion of a culture of peace *within* engineering. This will need the incorporation of increased degrees of compassion and generosity in the fulfilment of our tasks. In developing such a culture within engineering we have much to learn from the medical profession, which also seeks the wellbeing of all but is fundamentally opposed to professional involvement in weapons development [10]. Resolving the root causes of conflict provides new commercial opportunities for the benefit of all.

A further task for engineers is to take greater responsibility for informing politicians and other decision makers about the capabilities of engineering – none of the documents concerning peace and security cited in this paper refers explicitly to engineering. The fulfilment of this task may be greatly facilitated if the promotion of a culture of peace *within* engineering is aligned with major international initiatives such as the UN's programme of action on a *Culture of Peace*.

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Philosophies of Sustainability and Engineering the Nuclear Fuel Cycle:
Scenarios for the Future of Nuclear Power

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As the threat of global climate disruption from the continuing increase in the release of carbon dioxide into the atmosphere from fossil fuel combustion becomes clearer [1], some prominent environmentalists are calling for a greater role for nuclear power because nuclear power is essentially carbon dioxide-free [2], [3], [4]. The future role of nuclear power, however, in creating a sustainable future is contested. One may think of sustainability as creating a society such that it "meets the needs of the present without compromising the ability of future generations to meet their own needs" [5]. According to the environmental organization, Greenpeace, "The world must get on a course to stay as far below a two degree Celsius temperature rise as possible. That course can only be reached by employing sustainable renewable energy and energy efficiency. Nuclear power is not part of the climate solution, but an expensive and dangerous distraction"[6]. Greenpeace is effectively calling for "an end to the nuclear age" and recommends the following: "Phase out existing reactors; no new construction of commercial nuclear reactors; stop international trade in nuclear technologies and materials; and phase out all direct and indirect subsidies for nuclear energy" [6]. Similarly the U.S.-based Natural Resources Defense Council recommends that in the United States, "The crucial question for [the U.S.] Congress is whether to continue, curtail, or increase federal taxpayer subsidies to a mature, polluting industry in order to spur building new U.S. nuclear plants. . . . the answer to this question is a resounding 'no'" [7].

The environmentalists that think nuclear power should play a greater role in a sustainable future believe that reasoned, public deliberation would show that they are correct. Environmentalist and author of the *Whole Earth Catalogue* Stewart Brand writes, "The environmental movement has a quasi-religious aversion to nuclear energy. The few prominent environmentalists who have spoken out in its favor -- Gaia theorist James Lovelock, Greenpeace cofounder Patrick Moore, Friend of the Earth Hugh Montefiore -- have been privately anathematized by other environmentalists. Public excoriation, however, would invite public debate, which so far has not been welcome"[2]. What perhaps distinguishes the positions of opposing environmentalists are differing conceptions of sustainability as well as the type of engineered system that may be considered sustainable. This paper explores the philosophical differences between environmentalists that envision a sustainable nuclear power future and those that do not. An understanding of the reasons that justify these different positions will help clarify what is at stake to better enable intellectually responsible choices [8]. It is also a way to reaffirm an ethics of controversy [9].

The conflicted public discourse about nuclear power has deep and entangled roots. Although one of the main benefits of nuclear power is carbon dioxide-free electricity, there are significant economic, environmental, and security challenges. Because of the inter-relatedness of these challenges, designing future engineered fuel cycle systems, which includes future institutional governance mechanisms, raises interesting questions of valuation and uncertainty, particularly questions of inter-generational valuation and justice. An early example of philosophical work focused on nuclear technology had examined nuclear weapons and the human condition [10] while a contemporary and highly influential work that has informed public policy examined the value judgments inherent in risk analysis for the disposal of nuclear waste [11]. This paper examines how value judgments inform evaluations of different nuclear fuel cycles. The evolution and development of different fuel cycles and governance regimes, particularly issues regarding the reprocessing of spent nuclear fuel and the accessibility of enrichment technology, are central to the discourse about the sustainability of nuclear power [12]. Clarifying the reasons why advocates prefer one fuel cycle system to another thereby deepening the understanding of the nuclear power economic-environment-security trilemma is essential to judging and deciding the role nuclear power ought to play in a globally sustainable energy system. This paper lays out arguments and reasons for conflicting interpretations of different nuclear fuel cycles as well as proposes scenarios that may inform the public discourse about nuclear power in a sustainable future [13].

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Intergenerational future of nuclear power
Equity as a universal language to assess fuel cycles[1]

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Carbon-caused climate change and projected future energy demands pose serious challenges to the future of fossil fuel. While some believe that we can meet this challenge by tapping renewable resources, others maintain that in the future, nuclear energy will be indispensable. At present nuclear energy accounts for approximately 6 percent of global energy consumption and 16 percent of global electricity production [1]. A considerable growth of more than thirty percent by 2030 is foreseen [1, 2]. Future growth predictions depend on how well nuclear plants operate, the resolving of the nuclear waste disposal issue, proliferation concerns, international agreements on greenhouse gas reduction as well as rising oil prices. Nuclear energy engenders controversy in public and political debates that may well prevent its expansion.

In this paper we propose a framework of *intergenerational equity* [3] to assess current practice of nuclear energy production in the United States and its future. The "achievement of intergenerational equity" is one of the cornerstones of nuclear waste management [4] and one of the reasons for choosing geological repositories for the final disposal of nuclear waste [5]. Many nations are currently considering alternative fuel cycles to prolong uranium fuel supplies and manage nuclear waste. These strategies bring benefits and burdens for present and future generations; the choice between present fuel cycle has already been approached as a matter of intergenerational equity [6]. This paper proposes a methodology to assess future fuel cycles according to the intergenerational equity criteria, presented as a broadly defined and objectively formulated set of values. Values are general normative convictions and beliefs that people hold paramount in describing a good society, but the inherent difficulty is that the value system one adopts defines how one perceives public interest. With nuclear technology it has been found that stakeholders' value systems largely define their acceptance of courses of action [7]. We, however, argue that stakeholders attitudes towards an action relate to the how values are prioritized, rather than to how they are perceived.

We take here sustainability as meeting "the needs of the present without compromising the ability of future generations to meet their own needs" [8] as the overarching moral value. Sustainability can be assessed by considering the specific values which contribute to it such as: *environmental friendliness* - preserving the environment and leaving it no worse than we found it; *public health and safety* – achieving "the same degree of protection" for people living now and in the future [9]; *security* – avoiding intentional harm and any "deliberate act […] which could endanger the health and safety of the public or the environment" [10]. The latter also pertains to proliferation concerning fissile radioactive material for use in nuclear weapons.

Sustainability can also be viewed as moral commitments to sustaining human well-being now and in the future [11]. We may distinguish between *resource durability* – the availability of natural resources or the providing of alternatives; *technological applicability* – scientific feasibility and industrial readiness; *economic viability* – the cost of new technology. The last three values are closely intertwined and gain relevance in relation to each other.

When addressing the tension between different interpretations of sustainability the notion of intergenerational equity needs to be considered. In doing so, we follow Stephen Gardiner's discussions of "The Pure Intergenerational Problem" (PIP) [12] in which he imagines a world of temporally distinct groups that can asymmetrically influence each other: "earlier groups have the power to impose costs on later groups [….], whereas future groups have no causal power over them". Each generation has access to a diversity of commodities. Engaging in activity with these goods culminates in present benefits and potential substantial future cost that poses the problem of fairness. This also holds for nuclear energy: the present and next generation will deplete resources. In addition, the production of nuclear waste, and its longevity in terms of radioactivity, also creates future cost and burden issues. We relate the PIP to the production of nuclear power and see future generations as "people whom those presently alive will not live to meet" [12, p.489]. We propose that fuel cycle choices should be evaluated on the basis of the value criteria outlined above and that the impact of each fuel cycle, its burdens and benefits for each generation, must be assessed. We have selected four different fuel cycles to show how this methodology might be applied by decision makers.

1. CURRENT PRACTICE: DIRECT DISPOSAL

Current practice in the United States involves irradiating uranium once in a light water reactor (LWR), and keeping spent fuel (SF) in interim storage above ground pending final disposal in deep geological repositories. There is enough reasonably priced uranium for another 100 years [2]. Assuming that nuclear energy will be deployed for a hundred years – which we define as one generation – the problem of fairness arises between Generation 1 that is benefiting from this form of energy production while bearing some of the burdens and future generations that will bear the safety and security burden of long-term nuclear waste disposal. Figure 3 provides a chart of each value with a summary of the impacts and benefits. The burdens, over generations, are illustrated in light gray and the benefits in dark gray. There exists here an interesting trade-off from the point of view that SF is stored/disposed of retrievably out of respect for next generation's freedom of action to recycle and reuse but that gives them additional safety and security burdens [13, p.254-7].

2. GNEP AND FAST REACTORS TO BURN ACTINIDES

In some countries, SF is currently recycled in order to extract uranium and plutonium to reuse in an LWR and to reduce the waste lifetime [14]. This method has attracted widespread criticism as plutonium has proliferation risks. A future scenario bringing the advantages of recycling but avoiding security burdens would be to have an integrated fuel cycle that extracts uranium as fuel and "burns up" plutonium, together with minor actinides, in fast reactors. This is termed the GNEP approach (Global Nuclear Energy Partnership) [15] or the Partitioning & Transmutation (P&T) of actinides [16, p.23] method. Before this type of fuel cycle can be deployed at an industrial level it needs to be further technologically refined [17] and made economically viable. Clearly the additional economic, safety and security burdens involved in developing and building these extra facilities will mainly be borne by Generation 1. In reducing the waste lifetime the GNEP approach substantially reduces long-term safety concerns for Generation 2.

3. FAST REACTORS AS BREEDERS

A fast reactor could also be used in a breeder configuration to breed (make) more fuel (plutonium). As uranium use in breeders is significantly more efficient, the uranium durability period increases to thousands of years [2]. As SF and the remaining waste of enrichment facilities could be used in a breeder, the front-end activities in a fuel cycle (mining, milling, enrichment, etc.) and the associated safety and security concerns will decrease. The production and deployment of plutonium in this cycle will, however, lead to different security concerns. Since LWRs will be phased out in the long run and replaced by breeders, Generation 1 will ultimately bear significant economic burdens for the benefit of future generations, thus facilitating adequate energy supplies and making long-term waste problems minimal.

4. DIRECT DISPOSAL IN STORAGE/DISPOSAL FACILITIES

This fuel cycle is a derivative of the direct disposal fuel cycle in that instead of closing the repository when full it is kept open as a long term storage facility so that next generation can decide whether the resource that is contained in the spent fuel should be used for energy production [18]. This option safeguards the next generation's freedom of action. This cycle considerably reduces security concerns for Generation 1 as SF is stored directly, thus simplifying disposal as SF heat is allowed to decay. It does however increase transport risks, as the radioactive SF must directly be transported to the storage/disposal facility and if Generation 2 decides to leave SF (because it has no economic value) very long-term safety concerns will remain unchanged.

Decision-making based on intergenerational equity considerations involves prioritizing proposed values and comparing each fuel cycle's burdens and benefits using a value weighting system which may differ from individual to individual. Should Generation 1 accept additional burdens in order to reduce burdens to their descendants (scenario 2) or increase their benefits (scenario 3)? Is transferring risk to the very distant future (scenarios 1 and 4) acceptable, as safety assessments show that the long- term exposure risk of a geological repository to future generations is very low [19]? How risk transfer to future generations and the problem of proxy consent [20] can be dealt with are also questions that require normative statements (value judgments) with regard to (temporal) risk acceptability.

Summary

In this paper we present a methodology that can help the decision maker choose between different scenarios by transparently assessing the burdens and benefits of fuel cycles and understanding the conflicts between generations. The same criteria could also be used to compare different non-renewable and renewable energy resources, which would be desirable since nuclear energy should ultimately be assessed as part of an overall intergenerational energy strategy.

[1] This paper is a contribution to an interdisciplinary MIT study about the future fuel cycle options for nuclear power; expected in January 2009.

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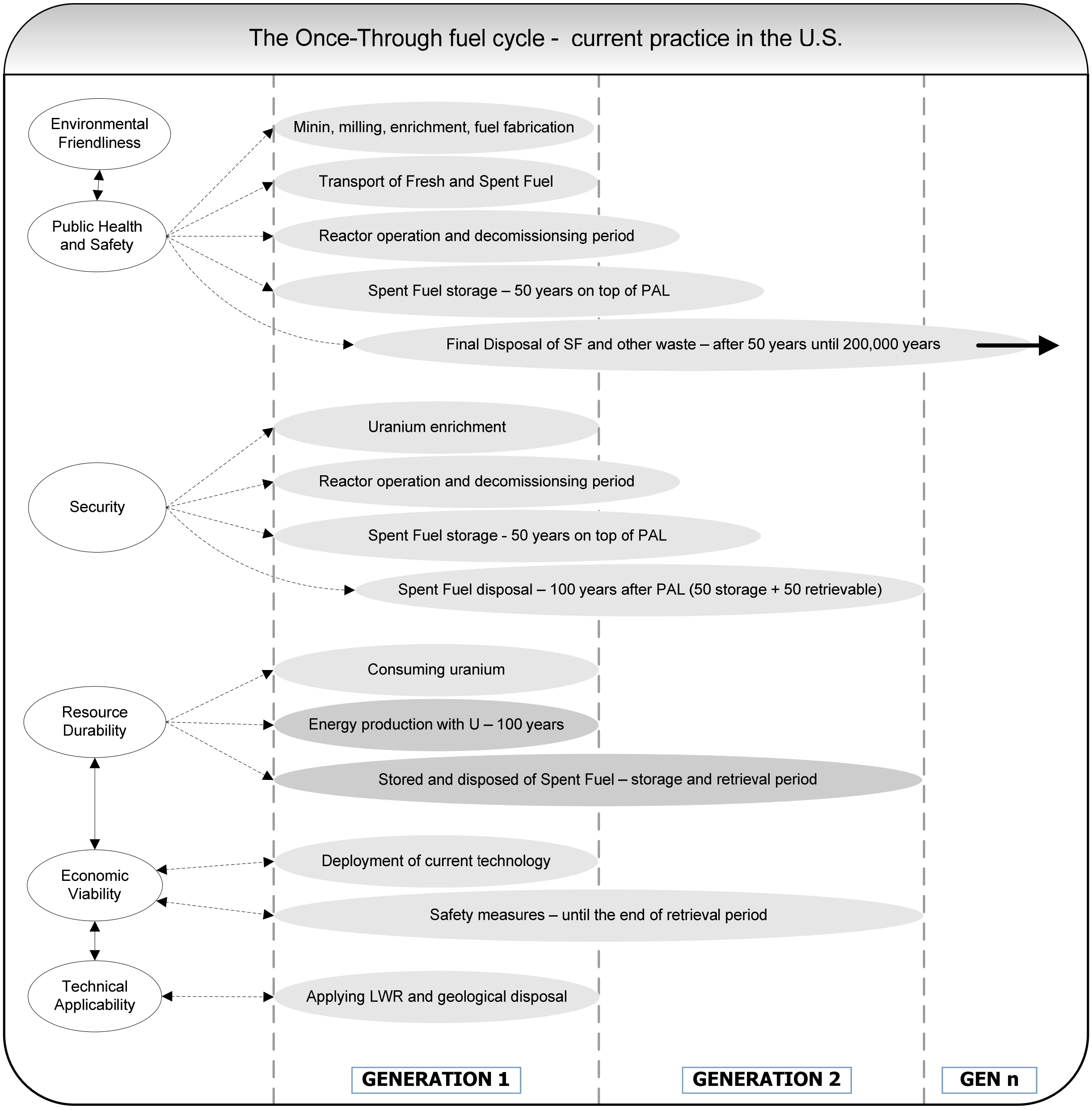

Figure 3: Relating moral values to concrete consequences and the associated *Period in which the Activity Lasts* (PAL); the light and dark gray ellipses represent the respective burdens and benefits.

Some Problems Defining Engineering—From Chicago to Shantou

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The term "engineer" does not seem definable in the way "dog" or "rock" is. There are, first, engineers who are not called “engineers”, such as naval architects. Second, there are non-engineers, such as the operators of railway trains, who are called "engineers".[1] Third, there are a number of disciplines not so easily separated from engineering proper—not only software engineering, re-engineering, and genetic engineering but even architecture, industrial chemistry, industrial design, and so on. One can define “rock” or “dog” without upsetting any rock or dog. Most definitions of engineering will upset some engineers (and some would-be engineers) if too narrow and upset both engineers and certain non-engineers (such as architects or chemists) if too broad. I therefore propose to reach the question of definition, or at least approach it, by a long detour.

Instead of offering and defending an abstract definition (as is customary), I shall look at a specific example of engineering (strictly so called)—a “hypothetical” compounded for convenience of several real cases. I shall set it in Shantou—Swatow or Suátao—a city of about five million people on the eastern coast of Guandong Province, in one of China’s booming Economic Development Zones. I shall set it there primarily because “Shantou” sounds good next to “Chicago” and because Shantou is not only physically far from the United States but also because it is what Americans tend to consider culturally far (as Australia, though physically farther, is not). I might have picked Timbuktu or Shangri-La but neither of these famously faraway places has a local polytechnic. Engineers there would have had to come from elsewhere (or at least have trained elsewhere)—making the problem I want to focus on less rather than more interesting.

7. The problem

You are an American-trained civil engineer working for a Chicago company that makes sophisticated industrial equipment. You are a “degreed engineer” but not a PE (that is, not licensed as a Professional Engineer). You are not unusual in this respect. Only about twenty percent of American engineers are licensed. You are in Shantou to help install a chemical mixer, a stainless-steel ball on stubby legs standing about thirty feet high and weighing several tons. Your job is quality control. The specifications require that the legs be bolted to a concrete base. Bolting is important because the mixer vibrates when in operation and, without the bolting, might move about unpredictably or even fall over. The chemical mix is not dangerous and the mixing ball is designed to keep the chemicals inside even if the ball is on its side. But, once free of its bolts, the mixer would be a danger to anyone close to it. For a few minutes, it would be the modern version of a “loose cannon”.

The concrete, bolts, and installation are standard in the US—and, indeed, around the world. So, to keep costs down, the concrete and bolts were to be procured in Shantou and the work done by local contractors. The concrete and bolts have been procured and you have tested them to assure quality. The bolts passed all tests “with flying colors”, but the concrete proved marginal (some samples passing, some failing, but all close to the line). Even in the US, you might reject the shipment (that is, refuse to sign the quality documents). Here, where there are (as you have been told) more problems of controlling quality during installation, you believe you need the full margin of safety the original specifications give.

You reported your findings to your contact, the local engineer in charge of assembling the new production line. She responded (in tech-school English), “Ah, we must give this supplier benefit of doubt. People’s Liberation Army owns company.” You asked around. and soon learned that dealing with the PLA is rather like dealing with some combination of the Pentagon, the Mafia, and Mayor Daley. You know what you would do in Chicago. You would not risk workers being crushed by a loose mixer—not to mention the cost to the client of repairs and to your employer in lost reputation. As your supervisor back in Chicago likes to say, “Sometimes an engineer has to say no—and take his lumps.” But this is Shantou. Should you act differently here?

The contract requires you, acting as your employer’s representative, to sign off on the installation. If you do not sign off, the legal consequence is that your company is not responsible for the mixer’s safety, reliability, or operation. The Chinese company cannot operate the mixer except “at its own risk”. You inform the local engineer in charge. She responds, “That’s good compromise. We don’t have problem with worker liability here. No lawsuits. Don’t sign. I can handle local inspectors. Everyone happy.” Have you done all you should? Has she? How are you to decide?

This case raises many questions, even ignoring the three just explicitly asked. I shall begin to answer them by considering what our American engineer, “you”, should do in the United States in a similar situation, then whether different standards apply to you outside the US, and then whether different standards might apply to a Chinese engineer working in China. By the time I am done, I will also have sketched a definition of engineering. I shall conclude with a few reflections on that definition.

8. The American engineer at home

The first question we are to consider (what more “you” should do) seems the easiest to answer. For a civil engineer, at least three codes of ethics are relevant “back home”: a) that of the American Society of Civil Engineers (ASCE), b) that of the National Society of Professional Engineers (NSPE), and c) that of Accreditation Board of Engineering and Technology (ABET). In theory, the status of these codes is straightforward.

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[1] . See, for example, the popular folksong “Casey Jones”:

> Come all you railroaders if you want to hear
> A story about a brave engineer,
> Casey Jones was the rounder's name,
> It was on a heavy eight wheeler pulling an IC train.

The IC (Illinois Central) ran between New Orleans and Chicago (almost passing my door).

Each applies to "engineers" as such, not to members of the enacting association (as one might expect of the ASCE or NSPE code) or to "Professional Engineers" (as one might expect of the NSPE code). All three state *professional* obligations rather than obligations arising from license or membership in a technical, scientific, or social organization.[2]

In practice, however, the relationship between engineers and these codes is more complex. While most engineers believe themselves to have a professional code, almost no engineer, as far as I can tell by asking engineers I meet, has ever consulted a code of engineering ethics to make a decision. Indeed, few have even seen a code of engineering ethics. Yet, when I go through one of these codes line by line with American engineers, they generally respond in one or both of the following ways. First, they agree to almost every line of the code, that is, they say something like "Yes, that's how I want other engineers to act, and I am willing to do the same if that's what it takes to get the others to do it." Second, they react with some combination of surprise and relief: "I didn't know it was all written down like that—and that I agreed with other engineers on so much. I thought I was an outlier."

Engineering education seems to hardwire much of engineering ethics into engineers. The hardwiring is done so subtly that engineers often do not realize that they agrees with other engineers concerning how engineers should act. Because they do not realize they agree, they are less likely to raise ethical issues than they would be if they expected the engineers around them to agree with them. They are less likely to act ethically than if they expected their fellow engineers to agree. For that reason (among others), I think engineering education should routinely include discussion of engineering ethics problems like this one in otherwise "technical" classes. But I digress. I was discussing the three codes.

There are significant differences between the three. They are nonetheless consistent. One or another simply sets a higher (minimum) standard than the others on this or that point. For example, the ASCE code has language about "sustainable development" that the other two lack. More important now, the provisions relevant here are, in substance, the same. The first "Fundamental Canon" in all three codes require engineers to "hold paramount the health, safety, and welfare of the public". That brings us to our first question of interpretation: Are workers, such as those a loose mixer might crush, members of the public (in the relevant sense)? Are engineers responsible for their safety?

I have discussed this question before—in an article on the Challenger published almost two decades ago.[3] The article is often cited, and has even been reprinted several times, but no one has, as far as I can tell, ever objected to the answer I gave there. So, I think we may treat it as uncontroversial. "Public" refers to all those persons, even those working for an engineer's client or employer, who, owing to ignorance, powerlessness, or lack of competence, cannot protect themselves from what engineers do (alone or with the help of others). A worker is a member of the public if the risk is, for example, concealed—as the unusual risk of the mixer breaking free of its substandard bolting would be. Part of every American engineer's job is to protect workers from such risks. A worker is not a member of the public only with respect to those risks she knows about, understands, and can avoid (for example, the well-known risks of the job she can avoid simply by taking a different one).

How should an engineer protect workers from risks that workers do not know about, do not understand, or cannot avoid? Let us continue using the ASCE code. Because its Fundamental Canons say no more relevant here, we must turn to the "Guidelines" that interpret the Fundamental Canons. According to one (1.2), "you" have already taken one action you may be required to take: "Engineers shall approve or seal only those design documents, reviewed or prepared by them, which are determined to be safe for public health and welfare in conformity with accepted engineering standards." You have declined to approve the quality control document that would say that the installation, which you consider to be substandard, meets the relevant standard. (We may, I think, interpret "design documents" to include quality control documents in support of carrying out an engineering design.)

That, however, is not all you are required to do. Your Chinese counterpart seems ready to overrule your judgment. The ASCE's Guidelines (1.3) also say: "Engineers whose professional judgment is overruled under circumstances where the safety, health and welfare of the public are endangered…shall inform their clients or employers of the possible consequences." Interestingly, the Guidelines do not consider this sort of informing to be solely a matter of protecting the public. There is a similar provision under the canon protecting clients and employers: Guideline 4.5 reads: "Engineers shall advise their employers or clients when, as a result of their studies, they believe a project will not be successful." If you consider the mixer's faulty installation a failure of the project you were sent to China to carry out—reasonable, I think, since you were sent to China to ensure its proper installation—you have an obligation to notify both your client (the Chinese company) and your employer back in Chicago.

Because you have already informed your Chinese counterpart of the risk, you must now decide whether that is enough to inform the client. How much can you count on your counterpart to share with her superiors? How likely is what she tells her superiors to reach those managers who should decide such a question for the company? However you answer those questions, you should let your superiors back in Chicago know about the problem. You will need their backing. Their resources for constructing a solution are greater than yours (they may, for example, be able to talk to the President of the Chinese company, something you probably cannot do, or augment your

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[2]. Not all engineering codes of ethics are like this. The most important that is not belongs to the Institute for Electrical and Electronics Engineers, Inc. (IEEE). It applies only to "members"'. There is, I think, a good explanation for this. A fair number of IEEE members are not engineers but computer scientists. That may also explain why the IEEE code is so short (agreement between engineers and non-engineers being considerably less than between engineers alone). Recently, this was made explicit with a proposal to substitute "technological" for "engineering" in the code so as not to "give the appearance of marginalizing those who are not engineers but nevertheless are dedicated technical professionals". http://www.theinstitute.ieee.org/portal/site/tionline/menuitem.130a3558587d56e8fb2275875bac26c8/index.jsp?&pName=institute_level1_article&article=tionline/legacy/inst2005/sep05/9w.nrevisions.xml&;jsessionid=bS8HHpMGvNQ1dh7jpfL7D4L9N6420fv1LSQfHhyklVXJtQfDps2H!-206324732 (March 25, 2008).

[3] Michael Davis, "Thinking like an Engineer: The Place of a Code of Ethics in the Practice of a Profession", *Philosophy and Public Affairs* 20 (Spring 1991): 150-167.

budget to pay for some "fix"). And, of course, no manager wants to learn of a problem like this when it is too late to do anything about it. Notifying your superiors is prudent as well as ethical.

Your responsibilities do not end with notifying client and employer. Should informing client and employer not resolve the problem to your satisfaction, the Guidelines (1.4) require you to do something more: "Engineers who have knowledge or reason to believe that another person or firm may be in violation of any of the provisions of Canon 1 shall present such information to the proper authority in writing and shall cooperate with the proper authority in furnishing such further information or assistance as may be required." "Proper authority" would certainly include the Chinese equivalent of the Occupational Safety and Health Administration (OSHA), but might include international or American agencies as well. You would have to check with your company's legal department—and perhaps other experts—to know.

I may—for the sake of brevity—pass over the details of what the guidelines for the other two codes say about how an engineer should handle this situation. Though the language and arrangement of the relevant provisions differ somewhat, showing that they were not just copied from one source, they are in substance the same. The engineer must inform client and employer of the risk to the public. If informing fails, he must report the problem to an appropriate authority. For an engineer, in the United States at least, the public safety, health, and welfare each take precedence over the interests of client or employer, including any interest in keeping business information confidential.

9. The engineer in someone else's home

We have so far assumed that standards that apply to an American engineer at home apply to his conduct when far from home—"in another culture" (as we sometimes say). If a culture is a distinctive way of doing things, then China certainly has a different culture. Among the differences may be what Chinese count as safe enough. The Chinese seem to be willing to take some risks Americans would not. The dark clouds that make many Chinese cities look like Pittsburgh a half century ago certainly suggest that. Let us then agree that China is a different culture—and that the Chinese may not view safety as "we" do or even expect to be informed of risk as we do. Let us even agree that they prefer social harmony to individual autonomy. None of that matters now. While such differences may affect how an American engineer in China should act in many situations (for example, how he should raise a sensitive topic with a superior), deference to local culture should not extend to any ethical requirement—or so I shall argue.

The point of sending an American engineer to China is to have whatever advantages come from having an American engineer there. The Chinese have plenty of skilled engineers. What then are the advantages of having an American engineer do the quality control when installing the mixer in China?

One advantage of having an American do it, or least having "you" do it, is having an engineer who knows the equipment and how it should be installed. This knowledge may seem merely technical. But almost nothing engineers know is *merely* technical. Engineering knowledge differs in at least two respects from "mere technical knowledge" (what one finds, for example, in a report of research results in physics). First, engineering knowledge, to be of use, must be embedded in an engineer's judgment. And, unlike "pure knowledge", judgment is always an application of everything the judge knows, believes, or merely feels about the question before him.

Second, engineering knowledge has itself developed with certain practical ends in view. Often the end is obvious. For example, safety factors are developed to ensure a certain level of safety. They are not disinterested deductions from physics, chemistry, or biology. They are expressions of practical wisdom, for example, an intelligent response to what was learned from keeping good records of products in use. Thus, the safety factor for industrial bolts such as those to be used to anchor the mixer arose from experience with failure of earlier bolts, not only those failures that arose from normal use but also those that arose from common errors in manufacture and installation, misuse of machinery, and even poor maintenance. The American engineer brings with him an understanding of what Americans think safe—and judgments reflecting that understanding—an understanding only partially expressed in formal criteria. A Chinese engineer will have a similar understanding of engineering in China. That is why the judgment of one cannot substitute for the judgment of the other. They are both necessary for the proper installation of an American mixer in China.

The American engineer is in Shantou to exercise judgment, his American engineering judgment. If he does not do that, he might as well have stayed home, sending an installation manual in his place. Since part of American engineering judgment is ethical, as the codes of ethics make clear, the American engineer must bring his ethical judgment with him. Indeed, it is part of his technical judgment. Of course, he cannot impose his own ethics on his Chinese counterpart. Though he is more than an advisor, since he has the power to withhold his signature from the document certifying proper installation, he is not the superior of his Chinese counterpart. He can tell her what he must do but she will have to decide what she should do in response. Can he do more? Can he, speaking engineer-to-engineer, explain to her why she—as a Chinese engineer—should work with him to protect the safety of her Chinese workers rather than putting the interests of her employer first?

10. The Chinese engineer at home

The answer to this question must begin with a point that should be obvious but is often overlooked. Engineering is itself a culture, that is, a distinctive way of doing things (including the beliefs and commitments that provide the rationale for what is done). Indeed, in some respects, engineering is more powerful than, say, Chinese (or any other national) culture. Given her tech-school knowledge of English and a green card, our American engineer's Chinese counterpart could move to the United States tomorrow and work much as an American engineer would. She would find it harder to move to the north of China (where the local language, customs, and even food are quite different from Shantou's) or even to stay in Shantou but switch from engineering to law, medicine, or some other occupation. In this respect at least, engineering is a global culture preempting local ones.[4]

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[4] Engineers take this for granted, forgetting that many professions—including law and medicine—do not have the same freedom to move. When asked for an explanation for their freedom of movement, engineers are likely to point to the laws of physics and chemistry, saying that gravity works on a bridge in the same way anywhere in the world. They are, of course, right about gravity (which may explain why physicists, chemists, and other physical scientists can move about the world as freely as engineers). Those engineers might, however,

That is not the only respect in which engineering is a global culture. If we examine the curriculum at Shantou's polytechnic, we will find it differs in only small ways from that of any American engineering program. If we seek for an explanation of this common curriculum, we may find that Americans brought their engineering curriculum to China a century ago. If we do not, we will still find that both the Chinese and the American curriculum ultimately originated in France two centuries or so ago.[5] Why would the Chinese, with several thousand years of technical innovation, large-scale manufacture, and impressive construction, adopt a European approach to such things?

The answer to that question is doubtless complicated, but any satisfactory answer will include at least two elements. First, the culture that Chinese engineers share with engineers elsewhere allows Chinese engineers to work well with engineers elsewhere, not only directly as "you" are with your Chinese counterpart, but also indirectly, for example, when writing a description of parts to include in a catalogue for sales overseas or when anticipating the size of a bolt thread and which way it will screw. Engineers form one world-wide technological network. The Chinese join that network (in part) by employing engineers (that is, graduates of schools with a certain curriculum).

Second, the Chinese, like most other peoples, must have been impressed by what engineers achieve. There must, for example, be the Chinese equivalent of America's experiments with building bridges during the nineteenth century. For a time, anyone might design and oversee construction of a major bridge: architects, carpenters, inventors, gentlemen-amateurs, and so on. Eventually, though, experience with bridge failure taught Americans that engineers were better at building bridges than their competitors and governments began to require an engineer to approve the design of any bridge the public was to use.[6] Chinese engineers are as much beneficiaries of the world's experience with engineers as American engineers are. When a Chinese truthfully claims to be "an engineer", she claims ("professes") membership in an international entity, one defined by its distinctive ways of doing things. Insofar as she benefits by that claim (for example, by being hired as an engineer or by having other engineers treat her as one of them), she should do as engineers are supposed to do. To do otherwise would be not simply to "free ride" on engineering but to take advantage of what other engineers have achieved in a way damaging to the joint achievement.

There is, I think, a misunderstanding about codes of engineering ethics. When someone says "code", most people, including most engineers, think of a short document with the title "code of ethics", "ethical guidelines", "rules of practice", or the like. They do not think about the possibility that a code of ethics might be *implicit* in the technical standards all engineers share. The code would then be "unwritten" (in the sense of not being written in a single short document called "a code of ethics") and yet in writing (that is, written into all those formal technical standards). Though Chinese engineers have no formal code of ethics, they might still have an unwritten one (the one implicit in the technical standards they share with the rest of the world). Indeed, even if they had a formal code of ethics (as American engineers do), much of their ethics might still be implicit in the technical standards. Tacit knowledge is always a large part of what we know.

Whether Chinese technical standards do constitute an unwritten code of engineering ethics will depend, in part at least, on how Chinese engineers understand those standards. A code of ethics consists of morally permissible standards of conduct all members of a group (at their rational best) want all others in the group to follow even if that would means having to do the same.[7] If Chinese engineers view their technical standards in that way—at least when, in a cool hour, they reflect on them—then the standards constitute (among other things) a code of ethics for them. If, however, even after due reflection, Chinese engineers regard those standards as mere external impositions that they have no interest in having other engineers follow, then the standards are not a code of ethics for them—and they are, strictly speaking, not engineers but some other sort of technical manager.

Whether Chinese engineers are engineers strictly so called or another sort of technical manager is, of course, an empirical question—one a philosopher alone cannot answer authoritatively. Yet, I can, I think, offer at least two reasons to think Chinese engineers are engineers properly speaking. First, when I ask Chinese engineers I meet in the US or when I am traveling, they generally understand engineering standards as engineers typically do. That is, they regard those standards as helping to avoid waste, save lives, and do other good things, not as mere external impositions. They want other engineers to follow those standards; indeed, they want to do the same. I assume that the engineers I have met are, in this respect at least, a fair sample of Chinese engineers generally. Second, interpreting engineering standards properly requires understanding their purpose. The understanding in question cannot simply be an intellectual grasp of the sort that can generate plausible arguments but must include the visceral commitment that typically expresses itself in good judgment. The quality of Chinese engineering is, then, itself evidence for the ethics of Chinese engineers. You cannot fake good judgment; good engineering requires good engineering judgment; and good engineering judgment includes good ethical judgment. An unethical engineer is not a good engineer (though he may pass for one for a time).

We may then imagine a conversation between our American engineer and his Chinese counterpart that takes into account the similarities in their engineering culture as well as the differences in national culture. The American might begin by acknowledging the problem. "Well," he might say, "I've never had to face the Pentagon, the Mafia, and Mayor Daley rolled into one. I concede the problem. But we are engineers. We still have a responsibility to protect the workers from that mixer. Surely, you cannot believe risking their lives like that would be good engineering—and you want your engineering to be good. Right?" Assuming that I am right about Chinese membership in

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have wondered why physicians cannot move about the world as freely as engineers even though many diseases can. In any case, it is not bridges that are the same around the world but bridges built by engineers. Before engineers took over bridge building, building a bridge was a skill not easily transferred from one place to another. For example, the Spanish who first saw the Inca's suspension bridges had no idea what to make of them.

[5]. Michael Davis, *Thinking like an Engineer: Essays in the Ethics of a Profession* (Oxford University Press: New York, 1998), Ch. 1-2.

[6]. For a time, one major bridge in four failed within five years of construction.

[7]. For an extended defense of this claim, see my *Profession, Code, and Ethics* (Ashgate: Aldershot, England, 2002).

the international profession of engineering, she should agree. If she does, “you” (our American engineer) can continue: “ So, what we need is a way to avoid conflict with the PLA while satisfying engineering requirements.”

I see no reason why the Chinese engineer would not agree. What remains, then, is an ordinary engineering problem and several possible solutions. The two engineers may, for example, contact the PLA’s company (either directly or through some intermediary) to see whether the company knows about the problem with its concrete. Perhaps it does not and, being informed, would take the concrete back or provide some less expensive correction. (The PLA’s company will have its own engineers and they too will not want to be responsible for harm to innocent workers; they may be able to sway the relevant managers.) Should that solution fail, the American engineer and his Chinese counterpart might still change the installation to make up for the marginal quality of the concrete, for example, by anchoring the bolts in steel plates beneath the concrete. They may, of course, have to go to their superiors should the cost of such a change be significant. But, as that supervisor in Chicago said, “Sometimes an engineer has to say no—and take his lumps.” That’s as true in Shantou as in Chicago.

This conclusion may explain what might otherwise seem quite odd. Codes of engineering ethics, even those adopted by national engineering societies, typically apply to “engineers” (without qualification), not to “American engineers”, “German engineers”, or “Japanese engineers”. The codes ignore national cultures. The explanation for that surprising indifference to what most of us consider important, our nationality, should now be clear: engineers are engineers the world over—defined by their common culture.

What definition?

The definition of engineering implicit in the analysis of the case presented here clearly is not a classical definition—genus and species, necessary and sufficient conditions, or anything of the sort. What I have done is point out an institution or practice, the profession of engineering. That profession was not identified by what engineers do. Engineers do a great many things: test, testify, teach, manage, invent, discover, inspect, and so on. Engineers were identified by a common curriculum imparting a common discipline (a culture, that is, a shared way of doing certain things, the shared way we call “engineering”). The reason naval architecture is engineering (whatever it is called) while ordinary architecture and even landscape architecture are not, is that naval architecture shares a discipline with the rest of engineering. One has only to look at the naval architecture curriculum to see that it is naval architecture is engineering, not architecture. The reason other similar disciplines—software engineering, re-engineering, genetic engineering, and the like—are not engineering is that they do not share that discipline.

The exact contours of engineering’s distinctive discipline is not a matter of logic or abstract definition but of history, one philosophers must take into account if they are to understand engineering. Engineering might have had a somewhat different curriculum, one allowing industrial chemistry or software engineering to have become part of engineering. Indeed, nothing prevents that amalgamation from occurring over the next few decades. What cannot happen is that engineering should absorb industrial chemistry or software engineering without some change in at least one of the disciplines. The disciplines are as real as nations—and no more real than that.

Notes

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Varieties of Parthood
Ontology learns from Engineering

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1. INTRODUCTION

Ever since the first deliberately chipped hand-axe, humans have produced artifacts with a view to the different functions of their different parts, and ever since the first axe-head was fitted into a wooden handle, they have assembled artifacts out of functionally and structurally diverse components. In the thousands of years since then, artificers, builders and engineers have had daily currency with artifact parts, the wholes they compose, and the ways in which the parts are put together to make the whole. Philosophers by contrast have only very recently thought it worth analysing the concept of the part–whole relation. Of course the concept did not escape them: it is too ubiquitous for that. Plato worried about whether some abstract forms had others as parts; Aristotle pointed out the polysemy of the term '*meros*' (part) in ordinary Greek. But the concept of part did not move to centre stage in philosophical discussion until the late 20th century. At the beginning of that century, starting with some observations of Edmund Husserl, logicians, most notably Stanisław Leśniewski and Alfred North Whitehead, developed formal theories of part and whole, for which theories Leśniewski coined the term 'mereology'.

This talk will review the problems and controversies surrounding philosophers' treatments of parthood, and will conclude that their views, more prevalent than ever in that community, are simply too monocultural to account for the wide variety of part-concepts met with and required in applications, most especially in engineering.

2. PHILOSOPHICAL MEREOLOGY

Mereology was developed initially for mathematical purposes: as a nominalistically acceptable substitute for set theory (Leśniewski) or as a logical framework for geometry (Whitehead) By the late 20th century it had become apparent that the standard formal resources of philosophers (interpreted predicate logic and set theory) were insufficient to articulate the variety of problems in ontology and metaphysics [1], and mereology became a central instrument in the ontologist's toolkit, so that nowadays a significant proportion of metaphysical disputes turn on matters of mereology. Nevertheless, ontologists have tended to take over the strong algebraic assumptions of the early mereologists [2]. Partly as a result, a large number of the mereological problems which preoccupy metaphysicians have little or no relevance to engineering practice or theory. Despite this, the concept of part–whole in engineering is not a mere simple application, to be indicated in passing while sticking to the theoretical high road. On the contrary, the mereology of artifacts is rife with problems, for which the philosophical ontologist's mereology is of little or no use. It is the central contention of this talk that until the crucial differences between the "pure" mereology of philosophers and the "applied" mereology of engineers are more carefully articulated, there will continue to be a significant gap between their respective mereologies, rendering these largely mutually irrelevant. It is precisely the job of the *philosopher* to recognize and articulate such differences and to see that philosophical theory, no matter how abstract, does not become wholly detached from real-world considerations.

3. CONTENTIOUS PRINCIPLES

Philosophers have put forward two mereological axioms that go well beyond the analytic principles constitutive of the part relation. These are

EXTENSIONALITY (EXT) That things with the same parts are identical.

UNIVERSAL COMPOSITION (UC) That any collection of individuals compose a further individual, called their *mereological sum*.

UC in particular leads to ridiculous and absurd consequences, yet is defended by philosophers on both pragmatic and *a priori* grounds. Rather than enter into philosophical debate, in the spirit of (perhaps misplaced) ecumenism, let's give philosophers this concept and call it that of the M-part ('M' for 'mereological'). The question is whether other concepts of part are needed and/or preferable. Just to show how easily the philosophical debate can become divorced from common sense: two diametrically opposed positions, both anti-common-sense, are now seriously defended in the contemporary ontological literature. One says that there is really only one thing, and it has no parts (monism). The other says that there are only atomic (simple) things, and no complex objects (radical atomism). Such extremes have been rare since the pre-Socratics (6th C BCE). Comment is hardly necessary.

4. ADDITIONAL PART-CONCEPTS

4.1 Physical Part

One perhaps not wholly determinate concept, but one which is certainly worth using and trying to get more determinate, is that of a *physical* part, or P-part. Consider a metal bar. It might be cut at the centre into two pieces, but suppose it is not. Each of the two halves is a physical part of the whole, even though neither is a detached physical body. By a physical part we mean a part that could if separated from the rest be a physical object in its own right. To a first approximation, a P-part is one which is in a suitable sense causally internally connected, but not in general a maximally connected whole. Even such arbitrary parts as the left-hand half of a car are physical parts: were such a car sliced in two (as was once portrayed in a James Bond movie) the left half would become a physical object in its own right. By contrast, the object considered by taking the sections of the bar at 1–2 cm from one end, and 3–4 cm, and 5–6 cm and so on, is not a P-part of the bar, because removing the rest does not give a physical object but several physical objects. Of course we could fuse these together somehow to give one object, but then they compose something *new*, and that's the point. Of course we may want to distinguish between *connected* and disconnected P-parts: there may be some genuine (not merely topological) basis for that further distinction. For the moment however let's stick with this first additional concept. All P-parts are M-parts, but not vice versa. M-parts need have no internal causal cohesion whatever: that's one of the things people don't like about them.

4.2 Salient Part

There is also a somewhat vaguely delimited notion of part of something which is in some way *salient*. Call these S-parts. A part may be salient (to a given set of potential observers via one or more sensory modalities) by virtue of its geometric prominence, or its material or qualitative discontinuity with adjacent parts. An example of a salient part (which is always a physical part but not necessarily vice versa) is the lower part of an aircraft fuselage which is painted a different colour from the upper part. For example the upper part may be white and the lower part may be blue. The shape of the line separating the two parts may be deliberately chosen for example to emphasize speed, or to look elegant. Salience in this case indicates that the part is intended to be discerned. But sometimes a part may be salient unintentionally or incidentally, as for example the carburettor bulges on older sports cars sometimes are (of course in time such bulges came to be associated with power and speed, so designers took pains to put them in just to advertise those connotations).

4.3 Engineering Parts: D-A-R-T

Now let's bring engineering into the picture. For any artifact that might be interesting to an engineer, some parts are more important than others. Not all p-parts are important. So call e-parts all parts that are of interest to an engineer. This is not a wholly objective demarcation so again let's try for a bit more precision, in the knowledge that improvement is incremental. Parts play different roles in engineering depending on what stage of the life-cycle of an artifact we are considering. A part which is envisaged as a unitary part during the design of an artifact we call a D-part. One which is manipulated as a separate individual during assembly we call an A-part. One which is manipulated as a separate individual during repair we call an R-part. And finally one which is manipulated as a separate individual during retirement we call a T-part ('T' as in 'reTire'). That gives dart as an acronym. It is possible for a given physical individual to play all four roles, D- A- R- and T, in the economy of a complex artifact. A door of an automobile might be an example. On the other hand, the exigencies of design, manufacture, maintenance and retirement mean that there are frequent discrepancies: what is designed as a D-part may come together only incidentally in manufacture, e.g. the braking system of a truck is never manipulated as a unitary separate object. Modular replacement and repair mean that many A-parts are never R-parts: a sealed headlamp unit in an automobile is an R-part of the automobile which has many a-parts (the unit was assembled) but no R-parts (it is replaced as a whole). Discrepancies among the different kinds of part lead to the so-called *Multiple Bill of Materials (BoM) Problem*, which is a practical hurdle facing electronic documentation of the mereology of complex artifacts across their life-cycles. [3] We are *not* here saying there are four new concepts of part: what we are saying is that there are four different *roles* that parts (mostly P-parts) can fill in the life-cycle. And even parts which are not E-parts as here defined may be of at least passing interest to an engineer. Suppose a screw fails to hold a certain slightly friable material because its head is not wide enough, and the material works lose around the head. The engineer will take an interest in the screw head which is, we may suppose, a P-part but not an E-part of the screw (it was turned out of a single piece of material), in that s/he will expect the screw (*not* the head) to replaced by another with a wider head.

4.4 Functional Part

That brings me to a crucially important role for parts, the most important in regard to engineering, which it is vitally important to recognize and yet surprisingly difficult to make fully precise. That is the idea of a part which performs a unified *function* in the working of the whole artifact. Call this an F-part. For example, the screw head in the example just given is an F-part, since its function is to brace the screw against the material it is intended to hold down. We shall assume then that all F-parts are E-parts, since an engineer has to be interested in function. But as the example shows, an F-part need not be a DART-part (i.e. not any one of those). Some P-parts like the screw head are F-parts, but others are not. The left-hand half of the car is not an F-part. It will not do to invent *ad hoc* "functions" for such parts such as "holding up the right half" just to make anything an F-part. The function has to be describable independently of invoking the part in question. In this case it is not, since the right-hand half is obviously just the mereological complement of the left-hand half. By contrast a function such as "providing forward visibility while shielding occupants from the wind of forward motion" is a description of the function fulfilled by a transparent windscreen (windshield) on a vehicle, and could in principle be fulfilled by some other part or method, e.g. without considering practical feasibility) a repulsive force-field or forceful cross-draught.

5. MATERIAL FEATURES

There is another general concept associated with material objects (not necessarily artifacts) which is not a concept of a material part, but which is sufficiently similar and sufficiently important to require treatment here. This is the concept of a *material feature*. [4] One example is the cross-shaped recess in a screwhead, enabling it to be turned by a suitably shaped driver. Another is the helical thread on the screw with its V- or U-shaped section. Yet another is the hole in a washer or nut, which enables a bolt to pass through it. The teeth of a gear wheel are P- and F-parts of the wheel, but the recesses between the teeth, which allow it to engage with other gear wheels, are material features, not material parts. In general such features as holes, slots, grooves, recesses, cavities, edges, ledges, ridges, corners, waists, tunnels, surfaces and other interfaces are material features, and as the examples indicate, they are to be found among natural objects just as much as among artificial ones, for example in physical geography or human anatomy.

We can not here attempt a rigorous formal ontological definition of a material feature, not least because it promises to be complicated and may require several overlapping definitions to cover different cases. But we can offer enough by the way of characterization to make the concept's distinctness and importance clear. We mention four ways in which material features are like material parts, and two ways on which they are unlike them. Firstly, a material feature is, like a material part, a *located individual*. It is not a general property, or a relation, or a mass of material. As a located individual, it can reasonably be attributed causal powers, at least of a derivative, passive nature. A hole, slot, tunnel etc. *permits* the insertion or passage of light, matter, objects, constrained by its surrounding matter. In engineering, that it often its precisely what it is there for. Secondly, like material parts, material features generally have a geometrical *shape*, whether stably or fluctuating over time. Thus engineering blueprints, drawings, and their electronic successors, CAD files, can deal with features like holes in the same way in which they deal with parts, by indicating the boundaries of material parts. Thirdly, in a quite general but intelligible sense, a material feature is *something about* a larger object in much the way that a material part is. For that reason it is tempting in various contexts to describe and think of material features as weird kinds of part, *immaterial parts*. Of course such a conception is inherently confused, but it does signify our recognition of an affinity between parts and features, as well as our need to talk about features and give them their due. Fourthly, material features in engineering can have functions just as much as parts do. As indicated, a hole in a nut is there to allow a bolt to be inserted through it, while the thread on the inside of this hole is there to engage with the thread in the bolt and ensure a secure physical bond between them, as well as (by the threads' matched helical forms) allowing rotation to be converted into pressure exerted along the bolt's central axis in order to hold something firmly between the nut and the bolthead.

Conversely, a material feature is distinguished from a material part in two crucial ontological respects. Firstly, in general a material feature is not *made of* matter in the way in which a material part is. This applies in particular to those features which are obviously in some way concave. Obviously a hole or slot is not made of material like its surrounding matter is, otherwise it would not be there. We form a hole, slot etc. typically by *removing* matter. The hole etc. may be *filled* by something such as air or oil, fuel or hot gas, but that is different. A cavity persists as a feature despite being filled, and indeed its being suitably filled is often the point. The function of a rocket nozzle (the nozzle as material part) is to surround and define a complicatedly shaped cavity (the nozzle as material feature) through which hot expanding gas is designed to flow in a certain way. Secondly, the material feature nevertheless *requires* its adjacent matter in order to be what it is: a tunnel is not nothing (ask a tunnel engineer), but it is nothing without material surrounding it. In the jargon of formal ontology, material features are *ontologically dependent* on their adjacent material. How this dependence works varies slightly from case to case.

It should be obvious even from the few simple examples given here that material features are very important in engineering, almost as important as parts. The preponderance of similarities over dissimilarities between material features and material parts also explains why we are often tempted to consider features as a sort of part. Indeed as the rocket nozzle example indicates, we sometimes use the same word for both a material feature and the material that bounds it and on which it depends, although these are ontologically speaking wholly different entities. We might even want to call material features *quasi-parts* of the objects they depend on. It is worth considering to what extent the various distinctions drawn above among different subspecies of part can be applied to quasi-parts.

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Toward an Ontology for Systems-related Terms in Engineering and Computer Science

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1. INTRODUCTION

Our talk at the First Workshop on Philosophy and Engineering concentrated on the impact that different approaches to philosophy and different national cultures had on architectures of engineering systems. Here we emphasize differences in the meaning of systems-related terms other than generic architectures that are used in various engineering disciplines. Much misunderstanding but also some creativity arises from these differences. Our special emphasis is on the differences in the meaning of terms between Computer Science and traditional engineering disciplines. Socrates said, “The beginning of wisdom is the definition of terms.” Our first attempts at defining and categorizing systems-related terms occurred in 2002 and 2004 [1, 2]. Here we build on some of those definitions. Based on our discussions in the past few years with engineers of different backgrounds, we are able to point out differences that arise from the differing assumptions made in various engineering fields from those made in Computer Science.

2. FORM, FUNCTION, PERFORMANCE AND PROPERTIES

“Function” is a word that has different meanings in different fields. In Computer Science the term usually means “what a system does.” That is, if a system is viewed as an input/output relation, then the function describes the transformation of the inputs to the outputs. Note that this definition does not involve the efficiency or other aspects of the performance of the system. Nor does function describe how the system arrives at its outputs either in CS or in mathematics. Function also is not closely related to the “form” of the system in these fields, where the concept form usually means the way the system appears as a connection of parts. Certainly a deep analysis of the form would help explain some or all of the function, but for complex systems such an analysis is too difficult to arrive at much of the time. Furthermore, the term function in CS usually does not give a hint regarding system properties, such as flexibility or robustness. Much of the increase in size and complexity of engineering or software systems arises not just from trying to achieve a given function with high performance, but also from trying to achieve additional system properties, such as flexibility.

Form is closely related to function in many engineering fields. In CS form does not usually relate to function as just noted, in part because there are many different forms (that is, programs which appear different) that can achieve the same function in CS. In fact, the number of software forms that achieve any given function is infinite. On the other hand, consider materials science. Here the form of the crystals that make up many solid state materials says a great deal about the properties of the material, such as hardness. In materials science creating materials with certain properties (and thus its function in materials science) is usually a key goal of an engineer.

In many engineering systems the function, in the sense that is what the system is supposed to do, is fairly clear and often relatively immutable. Thus it is not surprising that one tends in such fields to couple function with form and performance as well as other properties, such as flexibility. In CS, systems tend to be so flexible (and thus potentially perform many different functions over time) that one is encouraged to separate function from performance and other properties as well as form.

3. UNCERTAINTY

“Uncertainty” is a very important concept in most engineering fields. For example, in civil construction one does not often know up front the full nature of the subsoil. Hence one can say that there is uncertainty about the nature of the soil one will find. Engineers often resort to the use of ranges of values of uncertain variables or a statistical distribution for their values. In Computer Science uncertainty usually plays a far less important role. Indeed, one cannot usually be certain what the inputs to a software system will be. However, many algorithms, such as the ones in a digital calculator will work nearly equally well whatever the inputs are. Nor is it usually clear how to use a probability distribution on the inputs in order to help improve the function or performance of various computer algorithms. On the other hand, a calculator will usually have a limit on the number of digits in its inputs or outputs. Going beyond those limits will often result in an error. This rigidity or lack of robustness characterizes much software or digital hardware, and we shall discuss it further later.

4. COMPLEXITY

“Complexity” is a term that is used in a variety of ways. In Computer Science we have a notion called computational complexity. An algorithm is computational more complex than another if it takes significantly more time to obtain the result for sufficiently large inputs. Matrix multiplication is computationally more complex than matrix addition, although theorists have developed far more efficient algorithms for large scale matrix computations than the straight-forward ones. I believe that this use of the word complexity in Computer Science is unfortunate. The first paper that discusses these issues was entitled “Degrees of difficulty of computer algorithms [6].” I believe that “computational complexity” is better described as being about “computational difficulty.”

“Structural complexity” usually deals with systems that appear complex as a result of their large scale or relatively messy internal interconnection pattern. Another possibility is that the system is structurally complex because it has so many different component types that a human cannot fully fathom it regardless of the simplicity of the interconnection pattern. On the other hand, another person may see an abstract representation in his mind of a structure, such as a chess position, that makes it relatively simple based on that person’s experience. Thus structural complexity is a relative notion.

“Behavioral complexity” usually deals with systems whose behavior is difficult to predict or understand. Sometimes such behavior is exhibited when the environment is complex, although the system may not be. Consider the complex path created by a bug that is travelling along a complex terrain. The bug's path-following algorithm may not be complex, but the environment causes the path to appear to be complex.

Why is there so much discussion of complexity in recent years? We believe that the actual measure of complexity per se is not the issue that the man-on-the-street is usually concerned about. A very complex system is often difficult to modify, and the ability to make changes in a system is what people usually desire. The ability to make changes in a system is often related to its flexibility, an issue we shall now address.

5. DEALING WITH CHANGE – FLEXIBILITY, ROBUSTNESS, AND RESILIENCE

Large and complex systems undergo many changes during their useful lifetimes. Engineers and Computer Scientists build in various mechanisms for dealing with various classes of changes. A system is considered "robust" when it can maintain much of its original function and performance while it is being attacked in various ways. Note that a person with robust health will usually cope with influenza relatively well, and will get over it in a few days. Robustness does not tell us how a system achieves this wonderful property.

"Flexibility," like complexity, has multiple meanings. One meaning is that a system is flexible when it can be relatively easily changed in order to deal with classes of changes in its external environment or the changing desires of the system's function or performance by a designer. The need for change may also be internal to the system, as a result, for example, of the failure of a component or interconnection. Flexibility is related to robustness when there is a need to make internal changes to thwart an attack, but there is no desire to change the function of the system. The term "resilience," we believe, is usually used when one attempts to achieve robustness using flexibility as the technique for doing so [4].

In contrast to many system properties, flexibility hints at how it is usually implemented. A flexible system will have alternatives or options at various points in a system's implementation. A flexible system may possess very many alternative paths when one couples the alternatives at one point to alternatives at another connected point. In contrast, many engineering systems that are designed to be flexible will tend to have a far smaller number of alternatives. Consider the design of a parking garage. Let us assume we believe that a four story garage will make money, but we are uncertain that a six story one will until we actually build the garage and see the demand pattern. Thus building a six story garage is risky. A flexible design would have us build a four story garage with sufficient strength that it would be relatively easy to add the extra two stories if demand warrants it.

This example points out two issues. The number of strategic alternatives in the garage example is small, but millions of dollars can ride on each choice. That is, there is a high cost associated with switching between alternatives. Second, there is a trade-off between flexibility and efficiency. It costs somewhat more to build the smaller garage with the capability of adding to it than it would be to simply build a four story garage with no such alternative built-in. In software there would usually not be a major cost associated with adding an alternative. Note that an IF statement in software provides two alternatives, and its cost is usually not noticeable nor is the usual cost of switching between alternatives high. Adding trillions of alternatives will likely increase the complexity of the system, however, and this increase needs to be reduced with a carefully designed system architecture. The argument against built-in flexibility because of loss of efficiency goes back to the early days of computing when it was used against high level languages, such as FORTRAN. It was also used against IC design languages, data bases, middle ware and a host of other important abstract concepts in Computer Science. Fortunately, Moore's law has allowed computing platforms to increase in speed sufficiently to override such efficiency losses in many cases. Furthermore, experience with new abstractions also tends to reduce the losses in efficiency over time.

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Software tends to be brittle. That is, its behavior is often not robust when, for example, the inputs are outside the range expected by the system. It may be necessary for Computer Science to borrow approaches from other engineering disciplines, such as treating software systems as continuous as opposed to discrete systems, in order to achieve a significant level of robustness.

6. LARGE SCALE SYSTEMS

We concentrated in the sections above on the differences in meaning of terms between Computer Science and other engineering fields. Here we would like to note where the various views need to converge. We believe that while one could make a case for the differing interpretations of key systems attributes in small applications, in large scale systems it is very much advantageous to have the meanings be close to each other. Thus terms such as flexibility ought to have a single meaning in the large scale systems context because we believe that large scale energy-based systems and large scale information-based systems have common properties largely due to the scale and complexity. This convergence is of great importance as systems become large and more complex.

7. SUMMARY

Systems-related terms, such as form, function, efficiency, uncertainty, complexity, flexibility and robustness are used in all engineering fields as well as in Computer Science. The terms do not always mean the same thing. Based on our discussions with engineers from several different fields as well as our knowledge of Computer Science we present some of these differences in meaning. Computer Scientists as well as engineers in traditional fields have much to learn from each other.

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Emotion, Engineering and Ethics

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Emotion, engineering, Nussbaum, ethics, reflection.

1. CHANGE

Engineering is about change. Engineers play a part in designing new things, maintaining and operating things; they rectify faults and help regulate infrastructures.

Change brings benefits but can cause harm and introduce costs. An engineer's task is to guide change and to evaluate it. This evaluation can be wide ranging and consider energy use, material use and disposal, visual impact, the potential users and their foibles, reliability, cost, safety, impact on health as well as the technical aspects of construction, configuration and delivery. Additionally engineers must ensure their proposals satisfy regulations, laws, standards and the constraints of company policy and public expectations.

Broadly engineers ensure constructions behave inoffensively, reliably, safely and as specified. Often this requires much deliberation and discussion.

2. ECONOMY

To reduce biases and uncertainties in discussions, engineers employ techniques common to science. However there are limitations on resources, personal and physical energy and limits to the authority, locations and schedules of individuals. Available theories are bounded and disconnected. There are limits to what an individual engineer can absorb and to the attention others pay. Consequently, everybody has a personal archipelago of understandings, influences and goals. Within a engineering enterprise these personal economies stimulate differences of opinion that arouse frustration, anger, anxiety, elation, pride and so on, emotions which are quickened by clashes of loyalty to an enterprise, nations, humankind, animal kind, the public, family, colleagues and friends.

My intention is to explain how these emotions affect engineers and therefore warrant explicit attention.

3. EMOTIONS

Emotions, according to Martha Nussbaum, are "responses to…areas of vulnerability…in which we register the damages we have suffered, might suffer, or luckily have failed to suffer"[1, p.6]. They relate to people and things not fully under our control [2]. For instance, Nussbaum [1, p.13] presents fear as a burden imposed by "imagined bad possibilities", and anger as a response to damage to someone or something we are attached to — perhaps our self-esteem [3] or our reputation; joy is aroused when we learn bad possibilities may not happen.

Nussbaum takes her lead from the Stoics who saw passions not as bestial impulses, but as evaluative thoughts telling us about what we construe as significant damage hence what we value. The snag is, Nussbaum claims, emotions are unreliable indicators with unreliability arising from false beliefs about the dangers we face or from disproportionate reactions to threats.

The Stoics wanted to suppress emotions. Instead Nussbaum wants to recognize the contributions emotions make to our knowledge. For engineers this translates into a requirement to integrate experiences of emotions into engineering judgments.

Others too have hinted that emotions have a useful cognitive role. Allan Janik [4] noted that the enlightenment had an often forgotten theme summed up by David Hume when he famously wrote "reason is and ought to be the slave of the passions" [5, p.295]. However Pitcher [6] criticized Hume for his "traditional view" which parades emotions as sensations and inner feelings. Pitcher proposed adding processes of apprehension and evaluation though Solomon, who listed the aspects of emotions as behavioral, physiological, phenomenological, cognitive and contextual, claimed it would be a mistake to overstress the cognitive aspect of emotion [7, p.13]. Crucially though Solomon acknowledged emotions involve a system of judgments, beliefs and desires and a context that includes imagination and memory [8] and presuppositions [3].

4. JUDGEMENT

Within the rigid frameworks of engineering there is freedom, and while calculations guide choice, some factors are immeasurable or unknowable therefore inexpressible in any calculus. Even where there are well-defined rules, the rules can come into conflict. These conflicts and areas of ignorance render logical reasoning impotent but, irrespective of logical flaws, judgments are necessary to move a project forward.

Ultimately in an engineering project judgments interpolate between rules, what is known or incommensurate and here emotions offer guidance; as Nussbaum [2] explains emotions are forms of judgment. For those things that are uncertain, unfamiliar or rough-hewn, emotions guide by revealing the value we attribute to objects like materials, theories, instruments and documents, opinions, assertions, assumptions and the people that express them.

Emotional judgments are typically spontaneous and unarticulated [3]. Scrutinizing and rationalizing the emotional experience is the kind of reflection that will likely bring a sense of proportion and adjustments that enable otherwise unreliable, ill-defined emotions to contribute constructively to an engineering debate. Such conscious examination potentially reveals a previously neglected evaluative dimension.

An individual's emotion may have relevance to a wider community. The emotion can denote harms and through its intensity offer a starting point for assessing the significance of the object of the emotion in a wider debate. But the emotional experience is only useful to an engineering enterprise if the emotion's cognitive content is externalized.

5. REASONABLENESS

Any judgment about engineered change can be labeled reasonable or unreasonable thus a legitimate subject for criticism, but especially judgments implied in emotions which are vulnerable to misinterpretation and self-deceit [8].

An engineering judgment that leads to harm may be considered reasonable because it prevents a worse harm. A judgment will be considered unreasonable when it is considered baseless, irrational, exaggerated or rooted in confusion between coincidence and cause.

In all these cases there is a normative element thus the assessment of reasonableness is itself the result of a judgment, which arouses supportive or confounding emotions that reflect thoughts about, for instance, the reasonableness of caring about vulnerable things or of controlling another person's actions — matters which are commonly elements of ethical debates.

6. EMPATHY

For an engineering project the emotions of obvious relevance are those triggered by a proposal for an engineered artefact that has the potential to cause or extinguish harm. Any artifact or engineering proposal can arouse emotional reactions, from users, bystanders or engineering colleagues, but for the engineer the awareness of possible damage arises mainly through being a knowledgeable observer.

The outward signs of an emotion can be tactically feigned or exaggerated. Accounts of emotions can be imprecise, or distorted. Furthermore, the engineer will have difficulty gauging from an emotional response what matters to the users or bystanders because of differences between the engineer and users or bystanders in location, psychology, culture, gender, ethnic group, age and so on. Worse, engineers might think of themselves "as like the self-sufficient gods…as people who believe themselves above the vicissitudes of life…inflict[ing]…miseries that they culpably fail to comprehend."[1, p.7]. Engineers require awareness and skill to benefit from observations of people's emotional responses.

7. PERSUASION

People have to be persuaded a project is worthwhile if it is to proceed. Reasons have be constructed and there is a set of words, Rorty [9] explains, we "carry about" to justify our actions and beliefs; where these words fail we can only resort to emotional displays or provocation, or as Rorty colorfully puts it "beyond them is only helpless passivity or a resort to force".

Where there is little common vocabulary, an engineer can exploit displays of emotion to impress on others how much he or she values things or can guide an audience towards discoveries about what they value by stirring their emotions.

Exaggerated claims of harm or benefit are effective rhetorical devices that waken emotions. Socrates was critical: he acknowledged rhetoric convinces, but asserted it does not "educate people, about matters of right and wrong"[10, §455a]. He classified rhetoric alongside "flattery" requiring a "natural talent for interacting with people"[10, §463].

Nussbaum [1] warns of such exploitation of emotional provocations directed at the character by giving examples commonly related to punishments — shame and disgust. The harm alluded to in such provocations relate to something personal and, occasionally, mythical or otherwise undeniable. Such emotions can be compelling but also disquieting, disabling, disruptive and even harmful. For instance, threats to sever personal attachments are coercive emotional provocations which hamper engineers who are fearful of the harm to their relationships with colleagues posed by any criticisms of engineering proposals.

Consciously inflicted emotional harms are not always considered unreasonable for instance in doctrines justifying self-defense. There are then a catalogue of emotions that can usefully drive a project forward but the object of some of those emotions are harms to individuals and this adds another ethical dimension to engineering enterprises.

8. CONCLUSION

Adopting Nussbaum's view provides grounds for recognizing those bursts of anger or delight and the responses to them that alter the course of development of engineering projects. Her case supports the view that our emotions offer authentic thoughts about authentic situations, and by ignoring emotions our judgments are liable to be deficient. At worst, without reflection an emotion hides an influential unarticulated and mistaken belief. But at best an emotion can be taken to be an indicator of relevant components of ethical arguments supporting an engineering project and the significance attributed to them.

So we might expect virtuous engineers to be aware of their emotions, of ways in which they exploit the emotions of others, to reflect on those emotions and to use the knowledge gained in their judgments. To be effective within this emotional soup they will have to be self-aware, articulate, persuasive and above all empathetic.

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The Technology of Collective Memory and the Normativity of Truth

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Keywords

Memories for Life, memory, truth, history, World Wide Web, lifelogging, individual memory, collective memory

1. INTRODUCTION

The last two decades have seen extraordinary growth in the development of small, democratised, fragmented efforts to establish collective memories for various groups and cultures, aided by new technology and media, especially collaborative Web tools [1]. This has led to considerable dislocation – one commentator has noted the apparent contradiction of an "obsession" with memory in a society "terminally ill with amnesia" [2]. In this paper I will examine some of the effects on memory, collective and individual, of the memory boom in the context of the spread of technology.

One terminological note: if human memory is a paradigm, then the application of the term to collectives or machines is metaphorical. In this paper, I shall not attempt to analyse the similarities and differences between the various types of memory. I shall assume only that they are distinct, and that individual memory is affected by the other types in at least some respects.

2. COLLECTIVE MEMORY

The nature of collective memory has often been disputed, although its importance is not [1]. The two particular disputes with which this paper will be concerned are (i) the relation of the individual to the collective, and (ii) the normativity of truth in this area.

A collective has a memory, or its own interpretation of history. A collective is also a possibly structured collection of individuals, each of whom has an individual memory. The first question is how the collective memory relates to the individual ones. Many have argued that the nature of this relationship has not really been explored [1]. Is a collective's memory the sum of the (relevant aspects of the) individual memories of its members? Those who agree tend to neglect the technology of memory as well as the ways in which cognitive and even neurological structures are affected by social processes, while those who disagree fail to address the issue of how social and cultural memory can be constituted by psychological dynamics [3].

The second issue is the normativity of truth. Of course, truth is generally normative for memory, but for a collective, memory has other important functions that provide rival requirements. Memory is not history; it is also required to sustain social cohesion, communal ties and values and public aspects of personal identity. Too strong a focus on literal truth may well undermine these rival requirements [4]. There are postmodernist arguments that truth has no place in history or memory (e.g. [5]) – if these are accepted, then truth cannot be normative at all, but for the purposes of this paper I assume these fail, and thus assume the *possibility* of truth being normative for both history and memory.

3. THE TECHNOLOGY OF MEMORY

Technological development has always influenced memory and its place in society. Plato's *Phaedrus* questioned the effect of literacy on not only the society but also the psychology of the citizens of Athens, encyclopaedias and libraries have been intended as information stores to supplement the capacity of individual memories [6], while universities function as cultural memories vital to innovation [7]. Mass media and photography changed the nature of our understanding of veridicality of memory. Technology has also allowed us to measure memory – the incredible feats in oral cultures, where certain people could apparently 'remember' long genealogies or histories, are exposed by mechanical recording as creative acts (no less impressive) with little or no connection with either the past or indeed previous recitals **Error! Reference source not found.**.

Digital technology, including the World Wide Web, has pushed the envelope further. Indeed, comparison of the purpose of the Web with Diderot's original description of the *Encyclopédie* is very instructive [9]. In this paper, as examples of memory-based technology I will consider the programme of research into *Memories for Life*, and the practice of *lifelogging*.

3.1 Memories for Life

The capacities of digital storage and retrieval systems have become so impressive that very rich traces from an entire life can be stored [10], and research challenges such as the EPSRC's Memories for Life (http://www.memoriesforlife.org/) are intended to foster interdisciplinary research in this area. Lives are being mapped out increasingly often by amateur users, sometimes going back generations via genealogical sites, sometimes focusing on the here and now using Web 2.0 technology such as social networks blogs and photo sharing sites. The storage and retrieval of information is being rapidly democratised.

The Web has also been used extensively to generate expressions of memory to create collective accounts of some event or period. The BBC's Memoryshare project (http://www.bbc.co.uk/memoryshare/) aims to create a "living archive of memories", while the Second World War has also been the focus of projects such as the Shoah Foundation Institute, which commemorates the Holocaust (http://college.usc.edu/vhi/), and the BBC's People's War (http://www.bbc.co.uk/ww2peopleswar/).

3.2 Lifelogging

Our daily lives leave behind evidence trails, and undiscriminating collection and curation of such evidence is called *lifelogging*. Lifelogging can be passive – storing the by-products of the life one would have lived anyway – or active – surrounding oneself with sensors and information capture tools to create as rich a picture of one's life as possible. Typical types of information to be logged include emails, documents, digital photographs and video, diaries/calendars, geodata using the Global Positioning System (GPS), music downloads, listening habits, blog entries and Web browser bookmarks and navigation history. The result for the user is a large store of information much of which will be trivial or ephemeral, but whose potential for associative recall is immense.

The value of such information can vary, and may not be clear even to the lifelogger at the point of storage. However, in an information-intensive age where the surrender of digital identity is a commonplace, lifelogging has the potential to reaffirm the individual's control. The lifelog is a constructed identity that outweighs the others simply by weight of evidence, complexity and comprehensiveness. It is likely to include other identities, and amalgamate and supplement them [11].

4. THE INTEGRATION OF HUMAN MEMORY AND TECHNOLOGY

Technology hardens the yardstick against which memory's veridicality is measured, by providing solid evidence about events in the past. Web technologies have gone further, by gathering subjective accounts of, say, the Second World War, and fixing them in time. Meanwhile, it is noticeable that when technologies such as photography appeared, artistic endeavour began to depict memory less in historical terms than imaginative ones. The melting or drooping watches of Dali's *The Persistence of Memory* satirise the idea of fixed time, while Proust's *Remembrance of Things Past* depicts memory as a mechanism for the imaginative recreation of a past world. Art seems to have tacitly surrendered its role as a standard which memory needs to meet.

Memory is of course a whole set of diverse capacities – episodic memory, short-term memory, semantic memory, habit memory all have their parts to play. The technology of memory focuses on particular types; it tends not to be involved with procedural or semantic memory, but is primarily associated with (a) the logging of facts, not all of which need to be associated with or generated by the subject, (b) remembering to perform tasks (often called future memory), and (c) bringing together narratives or other materials into fruitful juxtaposition to aid associative linking and recall.

This paper will argue that the technology of memory brings with it support for episodic, autobiographical and factual memory, as well as providing access to information generated by others to give a context for associative recall. The effect is to outsource the storage of information, so that human memory will have fewer facts to store, but will have to include information retrieval skills. There is also an inevitable shift away from the first-person perspective in some respects. There are fascinating overlaps with recent developments in the neuropsychology of memory here too, although these are beyond the scope of this paper.

With respect to the two issues cited earlier, we see important effects whose significance has yet to be fully digested, and whose discussion will be the main point of the paper. With respect to the relation of the individual to the collective, as memories become laid down technologically, there will be a tendency to move towards a model where the collective is the sum of individual memories, rather than a more integrated account, as the most frequently used technology is an aggregator of (possibly diverse) memories/accounts, rather than being a genuine integrator. However, this claim demands further analysis and raises further questions: for instance, what are the effects of algorithms that can measure the statistics of linking and downloaded, PageRank-style to produce lists of content ordered by relevance?

With respect to normativity, eye-witness accounts and testimony on the Web will not generally evolve with time. Hence the truth of a statement now is more easily checked for broad factuality, and immediate reactions and feelings can be fixed, and need not be judged with hindsight. Ease of access to such immediate testimony means that it can be seen unfiltered by anyone who cares to look. Hence an effect of the Web on collective memory is that it may well increase the normative requirement to truthfulness, possibly at the expense of other functions of collective memory.

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Social Heuristics in Engineering

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Modern engineering derived from engagements of military, artisan and other traditions with modern mathematics and science. It has a theoretical dimension called engineering praxis, and a praxis-informed action dimension called engineering practice. Engineering is typically practiced by large groups in complex, exigent and lethal situations governed, in part, by authoritative imperatives. Treatment of these situations by systematic uses of mathematics and science may not adhere to these imperatives. To compensate, tradition hands non-systematic or *ad hoc* devices down into engineering praxis, to elevate the will relative to reason in theory making, and into engineering practice to distribute the will more evenly in hierarchical work groups. B.V. Koen called such devices engineering heuristics, and discussed them as *ad hoc* alternatives to mathematics and the physical sciences.

The purpose of this essay is to extend Koen's work into the social dimension. We shall discuss *ad hoc* alternatives to the social sciences in engineering praxis and practice.

This engagement theme characterizes engineering as a modern invention, specifically, the result of engaging various traditions of practice with university studies in mathematics and science. In his book *Thinking Like An Engineer*, Michael Davis gives an historical account of courses of university study in engineering. In 1794 at L'Ecole Polytechnic du Paris, he observes, the first course of university study in engineering engaged military engineering with the then new calculus and Newtonian physics. Other themes exist.

The imperatives theme characterizes engineering as a consequence of social action. In his piece *Imperatives of Engineering*, Eugene Ferguson observes the existence of authoritative commands that organize and maintain order among the teams that do engineering.
Ultimately, such authority derives from society.

The heuristics theme characterizes learned works of engineering as metaphors of historical literature. For example, Turteltaub's *Justinian* can be compared with Gibbon's *Decline and Fall of the Roman Empire* as a work of engineering can be compared with a work of physics. When Gibbon talks about Justinian II he separates what is known from what is unknown and then moves on to tell a story worthy of being believed. When Turteltaub gets to unknown parts of Justinian's life he fills in the gaps with fictions: not merely entertaining fictions, but learned fictions which tell what might have happened or what could have happened. Turteltaub tells a story that is believable. Billy Koen calls the fictions in a learned work of engineering heuristics. Accordingly, while a learned work of physics seeks belief, a learned work of engineering seeks believability.

Two categories of heuristics are discussed: physical; and social. Physical heuristics most often appear first at points in engineering praxis where compensations are made for the abandonment of systematic uses of physical science or of systematic uses of mathematics to do physical science. They appear in journal articles, textbooks and samples of solutions to problems on licensing examinations. Inasmuch as engineering practice is praxis-informed action, these heuristics make their second appearances in engineering practice. Social heuristics most often appear at points in engineering practice where compensations are made for the abandonment of systematic uses of social science or of systematic uses of mathematics to do social science. They appear wherever engineering is practiced according to the traditions and protocols of individual groups, e.g. the design office of a particular engineering firm, military unit, or governmental unit. The focus of this essay is on social heuristics. Four cases are studied.

First, Walter Vincenti identifies a physical heuristic in engineering praxis, specifically, the conceptual part of the design process. Then, he traces accretions of that heuristic through the production and operation phases of engineering practice. Lastly, he identifies a social heuristic in engineering praxis which he calls "bottom up design," and he observes that the design process concludes with a social heuristic he calls "agreement."

Second, a part factual, part hypothetical case is studied in which a systematic method of engineering praxis is applied to a problem that lies outside the scope of the method, but the improper application is compensated for in engineering practice by a social heuristic, namely, the use of shared intuitions from experienced engineers.

Third, called PuCC, this social heuristic is an elaboration on Vincenti's observation of agreement as a social condition for ending an iterative design process. Whereas Vincenti observed rather informal means of achieving agreement, the Pugh method is a systematic, but not a proven method of sociological verification. Thus, it remains a social heuristic.

Finally, a case is studied that compares two methods of experimental design: DOE is mathematically systematic; the other contains a physical heuristic called OFAT. The comparison that was made was in the history of their uses. Engineers persisted with the use of the OFAT fully aware that the DOE existed, saying the OFAT was more easily used and appealed to their collective intuitions. This appeal counts as a social heuristic.
Over time, this history proved the two methods to be competitive in solving problems.

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Beyond the modern profession: rethinking engineering and sustainability

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Engineering has been understood as a thoroughly modern profession. Its professional institutions have their origins in the industrial revolution and engineers have a pivotal role in the applications of science and technology to the everyday life, commerce and culture that characterise modernity. The second half of the twentieth century witnessed deep questioning of modernity and its institutions. The ecological crisis and the continued failure of economic development to deliver benefits to the poor were major challenges to the modern ideal of continual progress underpinned by scientific discovery and technological innovation. Sustainable development emerged as a modern response to these modern crises and sustainability has become a chief concern for the engineering profession.

Sustainability aims to integrate ecological and social concerns into economic development and the technological systems and artefacts that engineers design, build and maintain. Ecological modernist models of sustainable development and engineering practice preserve the fundamental basis of engineering as a modern profession and extend its power in response to new crises. This is a pragmatic, though problematic approach which avoids deeper questioning of the nature of the ecological crises, the goals of sustainable development, and the basis for engineering expertise and practice.

Engineers have conventionally worked to create solutions to problems by applying practical experience and state of the art science and technology. Engineering knowledge and work has conventionally been separated from social and political concerns. Engineering projects and artefacts may be of great social and political importance but the role of the engineer has been idealised as being purely technical. Engineers design and maintain nuclear power stations to the highest feasible safety standards, but it is for society and politics to decide if nuclear power is an acceptable source of electricity. Engineers provide endless supply of water to households, but it is up to consumers to decide how they use this resource and for society to decide how to respond to the environmental consequences of over abstraction of water from the environment.

The modern standoff between technology and society is unlikely to lead to more sustainable ways of living. Creating efficient technologies is part of the contribution of engineering to sustainability but is not sufficient to address multiple ecological and social problems. Engineering needs to move beyond modern distinctions between society and technology to a position which acknowledges that society and technology are created through complex relationships between people and artefacts. This paper uses Bruno Latour's seminal work 'We have never been modern' and case studies from the history of water engineering in London to show that engineering has never actually conformed to the classic distinction between technology and society that underpins ideas of modernity. As such, a renewed understanding of the nature of engineering as a non-modern profession provides new opportunities for models of sustainable engineering practice that respond to the fundamental nature of contemporary ecological and social crises.

Reflections on Integrating Engineering Education within the Elementary School Curriculum

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Keywords

Philosophy and engineering, engineering education, models and modeling perspective, elementary school, mathematics and science curriculum.

1. INTRODUCTION

The need for young scholars that will study engineering at the university level and be involved in the next generation of innovative ideas that support our society's needs is nowadays greater than ever. The world's demand for skills in mathematics, science, engineering, and technology is increasing rapidly yet supply is declining across several nations (National Academy of Sciences, 2007). Recent studies reveal waning student interest in engineering, poor educational preparedness, a lack of diverse representation, and low persistence of current and future engineering students (Dawes & Rasmussen, 2007).

Engineering education for elementary school students is a new, yet increasingly important to the various fields of engineering and represents a new domain of research by mathematics, science, and engineering educators. Among the core questions that are posed in related research are the following: "What constitutes engineering thinking for elementary school children?", "How can the nature of engineering and engineering practice be made visible to young learners?", "How can we integrate engineering experiences within existing school curricula?", "What engineering contexts are meaningful, engaging, and inspiring to young learners?", and "What teacher professional development opportunities and supports are needed to facilitate teaching engineering thinking within the curriculum?" (Cunningham & Hester, 2007; Dawes & Rasmussen, 2007).

This paper begins a discussion on engineering education for young learners by addressing engineering education's goals. In particular, the paper presents an example of the integration of engineering education on elementary school mathematics curriculum, by discussing one approach to promoting engineering education within the elementary mathematics curriculum, namely through engineering model eliciting activities.

2. ENGINEERING EDUCATION FOR YOUNG LEARNERS

Among engineering education's aims in the elementary and secondary school is the understanding and appreciation of the problems engineers face, how engineering shapes the world utilizing important ideas from mathematics and science, and how it contextualizes mathematics and science principles (Dawes & Rasmussen, 2007). Engineering education builds on young learners' curiosity about the natural world, how it functions, and how people interact with the environment, as well as on students' intrinsic interest in designing, building, and dismantling objects in learning how they work (Petroski, 2003).

Among the successful efforts in introducing engineering education in the elementary mathematics and science curricula are the Engineering is Elementary (EiE) program in the National Center for Technological Literacy at the Museum of Science in Boston (Cunningham & Hester, 2007) and the Inspire program in the Institute for P-12 Engineering Research and Learning at Purdue University. Cunningham and Hester (2007) have identified three core goals of their Engineering is Elementary program, namely, to: (a) Increase children's technological literacy; (b) Increase elementary educators' abilities to teach engineering and technology to their students; and (c) Modify systems of education to include engineering at the elementary level.

The integration of engineering education within the school mathematics and science curricula is important for a number of reasons. Appropriate engineering experiences within the elementary school curricula can: (a) help students appreciate how their learning in mathematics and science can apply to the solution of important real-world based engineering problems, (b) lead to better preparedness of senior subjects, (c) highlight the relevance of studying mathematics and physical sciences, and (d) help students appreciate the usefulness of the various fields of engineering and the role of the engineer in the society. Students learn how to apply the engineering design process in solving real-world problems; they learn to think creatively, critically, flexibly, and visually, and to troubleshoot and learn from failure. From the teacher perspective, considering that the majority of them has no education about engineering concepts and thinking, there is a strong need to provide professional development and appropriate resources to scaffold their understanding and pedagogical strategies to be able to effectively integrate engineering experiences within the elementary mathematics and science curricula.

3. A MODELS AND MODELING PERSPECTIVE IN ENGINEERING EDUCATION

A means of integrating engineering education within the elementary mathematics and science curriculum is through the *models and modeling perspective* (Lesh & Zawojewski, 2007). The models and modeling perspective complements and enriches the engineering design process. According to the modeling perspective, the components of a basic engineering design process are: *Ask* (What is the problem? What have others done? What are the constraints?), *Imagine* (What are some possible solutions?), *Plan* (e.g., what diagram/sketch can you draw? Make a list of materials needed.), *Create* (Follow your plan and create it; test it out), and *Improve* (Discuss what works, what doesn't, and what could work better; modify your design to make it better; test it out.) (Cunningham & Hester, 2007). Using the models and modeling perspective, students have opportunities to create, apply and adopt mathematical and scientific models in interpreting, explaining and predicting the behavior of real-world based engineering problems.

In adopting the models and modeling approach, real-world engineering situations are presented to students. These situations, called Engineering Model Eliciting Activities (EngMEAs), offer students opportunities to repeatedly express, test, and refine or revise their current ways of thinking as they endeavor to create a structurally significant product—structural in the sense of generating powerful mathematical and engineering constructs. These engineering-based activities are realistically complex problems where the students engage in mathematical and scientific thinking beyond the usual school experience and where the products to be generated often include complex artifacts or conceptual tools that are needed for some purpose, or to accomplish some goal (Lesh & Zawojewski, 2007). The engineering modeling problems present a future-oriented approach to learning, where students are given opportunities to elicit their own mathematical and scientific ideas as they interpret the problem and work towards its solution.

An example of an EngMEA is one environmental engineering problem adopted and modified from the Engineering is Elementary program, namely the Water Filter Problem (English & Mousoulides, 2008). The activity entails: (a) a warm-up task comprising a mathematically rich story designed to familiarize the students with the context of the engineering activity, (b) “readiness” questions to be answered about the story, and (c) the problem to be solved, including tables of data. The data included both qualitative and quantitative information—the color grade of the filtered water, the precipitates grade, the cost of each filter, the time needed for each filter to filter ¼ cup of water, and finally, the materials used for each filter. The problem required students to use the data to develop a procedure to rank the filters from best to worst.

We briefly report here on the models developed by one class of 11 year old students in Cyprus. Students had no prior experiences with engineering modeling activities. Students created a number of different models that adequately solved the problem although not all models took into account all of the data provided. Student models varied in the number of problem factors they took into consideration (color grade, precipitates grade, cost etc.), and also in the different approaches they adopted to dealing with the problem factors. Some groups ranked the five filters in terms of each of four of the factors and obtained a total score for each filter, and then considered a relative weighting of the factors—cost was considered more important than the other factors and the remaining filters could then be ranked accordingly. Some groups related the materials used for each filter with the effectiveness of the filter; the most effective was the filter with the maximum number of materials used.

4. CONCLUDING POINTS

We have argued here for the integration of engineering education within the elementary mathematics and science curriculum and have suggested one approach to achieving this goal, through the models and modeling perspective. EngMEAs provide opportunities for students to deal with complex engineering contexts, to identify, formulate, and solve real-world engineering problems. Engineering education at the elementary school level can provide opportunities for students to explore fundamental engineering ideas and principles and furthermore to assist students in further developing their problem solving skills. Substantial more research is clearly needed in the design and implementation of EngMEAs and how student learning is generated.

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What Engineers Don’t Learn and Why They Don Learn It: and How Philosophy Might Be Able to Help

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Keywords

Engineering curriculum, curriculum reform, engineer of 2020, senior design course, engineering reasoning, engineering epistemology.

1. INTRODUCTION

Once again, reform of the engineering curriculum is in the air. In the United States, the National Academy of Engineering has published two reports, one specifying characteristics of the engineer of our times [1], and one calling for changes in the ways young engineers are educated [2]. A national engineering leader has independently called for significant reform [3], and the Olin Foundation has given $460 million dollars to establish a pioneering new curriculum at the Franklin W. Olin College of Engineering [4]. These efforts follow significant funding of eight Engineering Education Coalitions by the National Science Foundation, but a recent report laments the lack of diffusion of those efforts [5].

Although much money, time, and effort has been expended toward engineering curriculum reform, and some successful reform has been achieved, it is not clear that the writing and doing to this point have clearly articulated the central problems facing engineering education today. The purpose of this talk is to approach the problem philosophically and reflect on what engineers don’t learn as part of the usual engineering education and then to consider five reasons why engineering students don’t learn these things.

I start by considering the interesting opportunity for reflection afforded by the juxtaposition of a fairly standard cold war engineering curriculum and a quite modern and effective industrially sponsored senior design project course. I continue by asking what skills appear to be missing among engineering students who have successfully completed such a curriculum as they approach real-world projects. That inquiry leads to the conclusion that very basic critical and creative thinking skills are being missed, and the talk continues by asking for possible explanations of how such basic skills are not being taught or learned. Five reasons are examined, and the talk concludes by asking how philosophy might be useful in rectifying the current situation.

2. COLD WAR MEETS SENIOR DESIGN

The “standard” engineering curriculum of our time was largely set in the aftermath of World War 2 during the opening days of the cold war period of the 1950s. In the US, the Grinter report [6] called for an increase in science, math, and engineering science, and a diminution of shop subjects and graphics. These changes held sway until the 1960s when a number of educators were concerned about a return to engineering design practice in the curriculum [7]. Capstone senior engineering courses trace their beginnings to those discussions, and one of the early leaders in this movement was the Department of General Engineering at the University of Illinois. A Ford Foundation grant in 1966 led to the establishment of an industrial-oriented senior design program, and when the money from that grant ran out, the program was continued using contributions from industry sponsors.

Today, Senior Design in General Engineering continues with successful outcomes for companies and students alike. Currently, teams of three students work with a faculty advisor for an industrial sponsor on a project of practical importance to the company. Additional details about the course are available on the course website [8], but the point here is to reflect on this course and the opportunity it provides to diagnose difficulties in the engineering curriculum. Think about it. Here we have students prepared in a fairly typical engineering curriculum who go to work for the first time on a real engineering problem. It is the perfect opportunity to ask, “What don’t they learn?” As a faculty advisor in Senior Design since 1990, I’ve learned how to coach students to successfully solve their problems, but I am continually reminded, year after year, about the mismatch between the education a cold war curriculum provides and the dands of a real-world engineering problem. The next ection considers what’s missing.

3. 7 FAILURES OF ENGINEERING EDUCATION

The semester has begun. The projects are assigned, and teams of three student engineers and their advisors are ready to go on the plant trip, and find out what the project is really about. Over 18 years of advising such teams, I’ve found seven important skills that elude many students. Although there is significant variation, the following composite set of difficulties is common enough that most teams require coaching along most, if not all, dimensions discussed.

In particular, senior design students have difficulty

1. asking questions
2. labeling technology and design challenges
3. modeling problems qualitatively
4. decomposing design problems
5. gathering data
6. visualizing solutions and generating ideas
7. communicating solutions in written and oral form

Each of these is briefly considered in turn.

Questions. Students go on the plant trip, and the first job is to learn what the project is, what has been tried, what critical sources of data and theory exist, and what vendors have been helpful in solving related problems. Unfortunately, most student teams have trouble asking cogent questions. We call this a failure of **Socrates 101** in recognition of his role in teaching the world to ask.

Labeling. Engineering students learn math and science but are largely ignorant of technology itself and have difficulty labeling the components, assemblies, systems, and processes in their projects. Moreover, many projects provide novel patterns of failure or design challenge, and the students have difficulty *giving* such patterns consistent names. This is a failure of **Aristotle 101** as the systematic naming and categorization of concepts is often attributed to that philosopher.

Modeling. With sufficient coaching, students learn the names of extant components and processes and give names to novel design challenges, but then they have difficulty modeling design challenges *qualitiatively.* Of course, if the problem lends itself to simple calculus or physics computation, engineering students can plug and chug with the best of them; however, companies don't pay real money (currently $8,500) for someone to do routine engineering calculation. This is a failure of **Aristotle 102** or **Hume 101** because of the connections to categorization and causality.

Decomposition. With some help in understanding key causal and categorical relations the student engineers regain their footing, and then they have trouble decomposing the big design problem into smaller subproblems. We call this a failure of **Descartes 101.**

Gathering data. With the job separated into pieces, usually a number of the pieces depend on careful data collection from the literature or from the design and execution of careful experiments. The students' first impulses are often to model mathematically, but an efficient and effective solution often depends on simple experimentation or library work. We call this failure to resort to empirical work a failure of **Bacon 101.**

Visualization & ideation. Students have trouble sketching or diagramming solutions to problems, and more generally they have difficulty in brainstorming a sufficiently large number of solutions. Calling this a failure of **da Vinci 101,** the problem again is solved with some coaching. **Communication.** Finally, the students have solved the problem, done the experiments, put together the analyses, and largely solved the problem, and the time has come to make a presentation or write a report, and to quote the famous line of the Captain from the movie *Cool Hand Luke:* "What we've got here is a failure to communicate." Calling this a failure of **Newman 101** (Paul Newman), the situation again calls for significant faculty intervention.

4. WHY THEY DON'T LEARN IT

These failures are substantial, and they are as much a failure of general education as engineering education, but if an industrial product were to come off the assembly line with defects in intended functionality as substantial as these, we would be forced to admit that the design and assembly process was subject to a massive failure in quality control.
The more interesting question, however, is how such a failure has come to pass. The talk addresses five reasons why the curriculum doesn't teach the right stuff:

Engineering mistaken for applied science/math.
Engineering educators bought the mistaken cold war idea that engineering is essentially applied math and science (Vincenti, 1990).

Engineering reasoning and epistemology not articulated. One of the reasons why engineering could take such a wrong turn post war is that it did not articulate a strong alternative vision of how it thinks and what it knows.

Pedagogical solutions to philosophical problems. The literature of engineering education emphasizes pedagogy and assessment, and largely assumes that engineering content is correct and settled.

Almost no attention to organizational reform. Reform efforts assume that existing departmental structures are adequate for supporting change.

Scalability of reform efforts ignored. Many reform efforts assume unrealistic or unsustainable influx of funding or substantial changes in faculty attitudes.

The talk examines each of these in additional detail.

5. HOW PHILOSOPHY MIGHT HELP

Philosophy is important to repairing these difficulties, directly and indirectly. Better understanding of intellectual history and philosophical method should help fill the seven critical lacunae. Of the five problems of the last section, three are significant category errors that can be overcome by more careful reasoning. The talk concludes by suggesting that improved engineering education can be an important outcome of the current interaction of philosophers and engineers

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A systematic approach towards developing a Philosophy of Engineering

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The expression *philosophy of engineering* strikes a false note to some and perhaps even many engineers. The phrase carries the promise that something insightful and comprehensive and generic can be generated and articulated about engineering. The contention here is that this ambition has exceeded the reality. As a simple test can engineers point to anything in their field that has the same rank as Popper's *falsifiability* principle in science [1]. Or moving from science to mathematics has engineering in terms of fundamental truths an equivalent of Gödel's incompleteness theorems [2]. At one level the answers are no. Yet if it is accepted that engineering is a complex composite that includes or can include science, mathematics, technology, arts, crafts and aspects of the humanities, then it follows that engineering must inherit at least some of the philosophies of each of these endeavours, and so at this level the answer is yes. But this is not really a satisfactory avenue of thought for the simple reason that the collection of individual philosophies does not in itself describe how these individual components interact. And, just as for a system, engineering is more than the sum of its parts. In addition, as pointed out by Simon engineering is different: *the natural sciences are concerned with how things are; ... design, on the other hand, is concerned with how things ought to be, with devising artifacts to attain goals* [3]. Also, Durbin has concluded that it was unlikely that there would be one philosophy of engineering: rather there would be philosophies of engineering [4]. One can imagine why there might be a plurality of philosophies – nationally and culturally determined; a function of discipline (civil as compared to computer engineering) etc - but this would mean either having competing philosophies or having some kind of *à la carte* choice: and neither alternative is very appealing.

The kernel of the problem then is the 'mongrel' nature of engineering where its 'genes' are derived from multiple sources all the better to achieve whatever goal has been articulated. Another manifestation of the underlying problem is in the design of engineering curricula where balancing the contributions of science, mathematics, crafts, technology and what might unhelpfully be termed 'engineering' is an ever present challenge with each generation favouring a particular mix. David Goldberg has written about the 'broken curriculum' and has identified the need for the inclusion of qualitative thinking which he states has its roots in philosophy [5]. To some extent we thus have completed the circle: doubt has been expressed as to the achievability of having a philosophy of engineering and now it is suggested that philosophy is a fundamental topic in its own right for inclusion in an engineering curriculum!

Before proceeding with some suggested ways forward the matter of a description needs to be addressed as there is no clear commonly used definition of the meaning of 'philosophy of …' which might not be such a problem in some areas but constitutes a more weighty problem when it comes to an area as complex and diverse as engineering. The working meaning used here is based on the Oxford English Dictionary entry for philosophy- *In extended use: a set of opinions or ideas held by an individual or group; a theory or attitude which acts as a guiding principle for behaviour; an outlook or world view.* Because of the composite nature of engineering with its attendant multi-paradigmatic approaches a definition as wide as this is probably essential. The key to applying this definition to engineering is to characterize in some manner (a) what opinions and ideas are held and how they originated, (b) what attitudes prevail in determining behaviour and how they arose, and (c) the general outlook that is commonly held, what shapes it and how it reflects, or not as the case might be, societies views.
How then to proceed? Two approaches are suggested. First, by describing the main instances-awillias that contribute to (a), (b) and (c) above through the 'lens' of the five classical branches of philosophy which are taken here to be epistemology, logic, metaphysics, ethics and aesthetics. The objective being to create a profile that is the quintessence of engineering and thus sets the platform from which a philosophy of engineering might be expounded. Second, by making a comparison between engineering and another profession which shares, at least in some respect, several of the characteristics of engineering. The candidate profession being suggested here is Medicine as it too is based on a complex mix of disciplines. The objective in this case being a form of validation exercise where the test would be to check that the resultant characterisations of engineering and in this case medicine provide sufficient discrimination or specificity**,** since a generic outcome that says nothing particular about engineering would be of little use.

A little more detail about what is being proposed; consider the matrix below. Completing each entry in the matrix represents a set of non-trivial tasks and would require a battery of skills such as for example the ethnographical approach exploring the relationship between knowledge and personhood as promoted by Gary Downey [6]. Clearly there are sociological and historical aspects as well to populating the matrix. Fortunately there is a wealth of literature and material available to draw on and so the nature of the challenge is to a large extent one of assembling a coherent 'picture' from largely pre-existing pieces; and the stress here must be on the *coherence* aspect.

	Opinions and Ideas	**Attitudes that guide behaviour**	**Outlook, how it is shaped**
Epistemology			
Logic			
Metaphysics			
Ethics			
Aesthetics			

In carrying out the scheme a number of sub-approaches might be taken. For example some restriction on the aspects of the five branches of philosophy to be 'used' might be considered as follows:

Epistemology - understanding the distinction between different forms of knowledge (rational, empirical etc), to consider how knowledge is acquired, recorded, maintained and used, and to provide a platform by which the provenance and limits of applicability of knowledge may be evaluated.
Metaphysics – here it is practical issues such as taxonomy that can be included together with, ontological, mereology, and teleology considerations.
Ethics - placing value to personal actions, decisions, and relations. Impact of legislation, professional code of ethics.
Logic - concept of 'right reasoning', forms of logic (e.g. temporal logic), role of logic in building conceptual models, the role of logic in how knowledge is deployed.
Aesthetics – distinction if any between 'values' in arts, science and engineering. The tension or even dialogue between form and function. Since engineering involves making things that never were, the aesthetic issue is raised at each departure, and case studies would illustrate the concerns.

Another line to be explored is to consider the design cycle as a generic activity along the lines explored by Horváth [7], and it might be appropriate here to provide a statement or definition of the cycle as: *a systematic process, often iterative in nature, by which decisions are taken that ultimately lead to executable plans, addressing a set of requirements, by which resources can be transformed efficiently and effectively into products or systems, based on scientific and mathematical principles, and acknowledging best practice through the exercise of established or newly developed engineering paradigms, culminating in an evaluation of a product or system by which it is decided as to whether or not the design is accepted.* Concentrating on the key decision-making points illustrates where the above philosophical activities play a role in this design cycle and contribute to understanding what is different about engineering. Briefly, gathering, understanding and distilling user requirements to the point at which analysis and design can commence is a complex enterprise with for example a societal and ethical dimension often in the form of both implicit and explicit constraints. Continuing, in carrying out any analysis/design decisions have to be made on what scientific knowledge is available and applicable, and where a heuristic approach is the appropriate means. Much has been written on heuristics in engineering, by Billy Koen [8] amongst others, but the 'exercise of judgement' role of engineers as to what process to follow is of more significance than the details of the methods, in characterizing the work of the profession. To put it another way, the decision, say, to drop a potential scientific or mathematical line of study and adopt a heuristic approach needs to have a justification, and how that justification is made deserves attention. And there are, at least, epistemological, logical, and ethical activities involved. At the end of the cycle, evaluation takes place which doesn't necessarily occur once or at a single point in time. For example there is more to the evaluation of a nuclear power station design than just technical considerations: the technical, political, societal and economic threads that run through any evaluation cannot be dealt with by any simple process. The somewhat inadequate way that engineers interact with society and decision makers in such processes has been a topic that has been referred to by Florman but is not an area that has been well explored or understood: a good candidate therefore for philosophical reflection [9].
In conclusion, the two main points that are being made are that a philosophy of engineering is unlikely to emerge along the lines of science or other essentially homogeneous disciplines and a systematic way of characterizing engineering using the natural divisions and tools of philosophy is an attractive way of addressing the challenge.

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The Five *Epistemic* Phases of Technological Inventions: A Historico-Descriptive Model and Three Case Studies

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1. INTRODUCTION

The subject of this paper is a historico-descriptive model of the epistemic phases through which technological inventions evolve. Five such phases have been identified and clearly defined, and the 5-Phase Model has been tested - successfully - against historical data that relate to a number of well-known contemporary technological inventions, concise case studies for three of which are included here, namely: *The Microwave Oven*, *The Cyclonic Vacuum Cleaner* and *Chemotherapeutic Penicillin*.

2. THE FIVE PHASE MODEL

2.1. The Trigger Phase:

A technological trigger is either a *technological problem* or a *technological opportunity.* A technological problem is possible to express in terms of a *preferred empirical result* for which there is no established technological means to achieve. On the other hand, a technological opportunity can emerge from data; scientific models or Confirmed Technological Principles for none of which there exists technological exploitation outside their immediate or established contexts. Data triggers emerge from accidental observations, negative experimental data or previously perceived irrelevant data, while the other triggers emerge from newly established or previously perceived irrelevant scientific models or previously perceived irrelevant Confirmed Technological Principles.

2.2. The Eureka Phase:

The nature of the Eureka Phase corresponds to the nature of the Trigger Phase. If the Trigger Phase consists of a problem, the Eureka Phase consists of forming a *hypothetical solution*, and if the Trigger Phase consists of an opportunity, the Eureka Phase consists of forming specific *hypothetical exploitation*. At such an early stage, the hypothetical invention is nothing more than just a vague possibility. It is important to distinguish between the Eureka *Phase* and the widely used term “Eureka Moment”, as although the Eureka Phase can indeed start and end in a flash it can also stretch across days, months or even years.

2.3. The Technological- Bundle *Search* Phase:

Experimentation in technology is essentially *developmental*, as the hypothesis is not being “tested” as such, but is actually being “constructed” almost from scratch, by trying out different epistemic associations with other Confirmed Technological Principles until at least one set of such associations is finally found to make the hypothetical invention work. It is important to highlight that the epistemic focus at *this* Phase is the attempt to make the hypothetical invention work, without much attention being given to other epistemic aims that would *only* become relevant, *if* the hypothetical invention is proven to work.

2.4. The Technological-Bundle *Confirmation* Phase:

This is the Phase at which the invention is born as a *Confirmed Technological Principle* according to which, such and such novel empirical result *is* achievable using such and such epistemic associations. The statement of the “invention” at this Phase is not only more precise than that at the Eureka Phase, but it also almost always stipulates *conditions* without which the “invention” will either not work at all, or will not achieve a specific level of performance.

2.5. The Technological- Bundle *Refinement* Phase:

Following the emergence of the new Confirmed Technological Principle, at this Phase the epistemic focus finally shifts to the *refinement* of the technological bundle so that it accommodates numerous socio-economic requirements. Such requirements include the choice of materials, mass-producibility, cost, safety, user friendliness, environmental impact, aesthetics etc., the level of complexity of which varies considerably from simple inventions to complex ones.

3. THE MICROWAVE OVEN (PERCY SPENCER)

3.1. The Trigger Phase:

The trigger was the *technological opportunity* that emerged from the accidental observation of the effects of microwave emissions on a candy bar.

3.2. The Eureka Phase:

The eureka consisted of forming the hypothesis that a new method of cooking using microwave emissions might be possible.

3.3. The Technological- Bundle *Search* Phase:

Initial experimentation was instantly successful, in which popcorn and a raw egg were cooked after exposure to a switched-on magnetron (a radar part).

3.4. The Technological-Bundle *Confirmation* Phase:

Foodstuffs can be cooked by exposure to electromagnetic energy whose wave lengths fall in the microwave region of the electromagnetic spectrum, on the condition that the exposure is extended to predetermined lengths of time.

3.5. The Technological- Bundle *Refinement* Phase:

The first product was the "Radarange", which incorporated a cavity, a magnetron, a mode stirrer and a water-cooling feature, all in all weighing more than 300 kilograms. Numerous improvements were introduced over the following decades, culminating in smaller and consumer friendlier product-designs.

4. THE CYCLONIC VACUUM CLEANER (JAMES DYSON)

4.1. The Trigger Phase:

The trigger was the *technological problem* of the permanent clogging of vacuum cleaner bags, which leads to a rapid decline in extraction performance.

4.2. The Eureka Phase:

The eureka consisted of forming the hypothesis that filter separation (which is the principle on which bags work) might be possible to abandon in favour of cyclonic separation, using centrifugal force.

4.3. The Technological- Bundle *Search* Phase:

The first home-made, gaffer tape-sealed cardboard cyclone that the inventor connected to a traditional bag-operated vacuum cleaner (whose bag he had removed) was an instant success, as the dust was separated and deposited at the bottom of the cyclone. However a serious problem emerged, as it was not performing as well for larger objects such as fluff and fibre. The solution came in the form of introducing the *dual* cyclone.

4.4. The Technological-Bundle *Confirmation* Phase:

Vacuum cleaners can be operated using cyclonic separation, on the condition of using two cyclones of different shapes (and consequently different speeds). The faster cyclone picks up dust, while the slower cyclone picks up all the larger objects.

4.5. The Technological- Bundle *Refinement* Phase:

The first product included innovative functional features such as the telescopic hose and the use of a plastic with high rubber content, for the manufacture of the body of the vacuum cleaner to increase its durability.

5. CHEMOTHERAPEUTIC PENICILLIN (THE OXFORD TEAM)

5.1. The Trigger Phase:

The trigger was the *technological opportunity* that emerged from Alexander Fleming's 1929 paper, describing his accidental observation and subsequent research into the antibacterial effects that filtrates of a strain of Penicillium (which he called "Penicillin") have on some pathogenic bacteria.

5.2. The Eureka Phase:

Following Fleming's failure in converting his accidental observation into a chemotherapeutic drug, the Oxford Team's eureka consisted of forming the hypothesis that the antibacterial effects of a purified form of Penicillin might work as an *intravenously-injectable antiseptic* if tested *in vivo* (which neither Fleming nor anybody else had undertaken).

5.3. The Technological- Bundle *Search* Phase:

The first hurdle was the attempt to obtain a *purified* and *shelf-stable* Penicillin, which eventually succeeded using a combination of existing and newly established Confirmed Technological Principles in biochemistry. This was followed by the team's important innovation of conducting "animal protection tests", in which mice were injected with Penicillin-sensitive pathogenic bacteria followed by Penicillin (except the control mice). The survival of the Penicillin-treated mice indicated that Penicillin was active *in vivo* (in mice) against at least three types of pathogenic bacteria. Finally, the team proceeded with testing Penicillin on the human body, achieving unequivocal success.

5.4. The Technological-Bundle *Confirmation* Phase:

If injected into humans, purified and shelf-stable Penicillin can be used as a chemotherapeutic drug against some pathogenic bacteria to treat *both* externally accessible infections of skin or mucous membranes and deep-seated infections inside the body.

5.5. The Technological- Bundle *Refinement* Phase

The first Penicillin product was the *slow intravenous drip* that was produced by the Oxford Team using *surface culturing*, whose production yield was so low the use of Penicillin on a wide scale was deemed unrealistic. The Oxford Team sought the assistance of the Research Laboratory in Peoria (USA), which introduced product innovations (including *deep-fermentation*) the combination of which took production levels from two to eight Oxford Units per millilitre to 500 Oxford Units per millilitre. The Oxford variant of Penicillin became known as Penicillin F, whereas the American variant became known as Penicillin G and became the dominant variant in clinical use for many years. In the mid 1950s the more robust Penicillin V was introduced, which was able to withstand exposure to gastric acid, and was subsequently used in orally active Penicillin products.

Post-Enlightenment Philosophical Ethics and its Implications for Practical (and Professional) Ethics

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The 20th C. saw major challenges to Enlightenment Ethical Theory (EET) from some of the most respected English-speaking philosophers, philosophers who often disagreed with one another about other matters. This paper briefly reviews that post-Enlightenment approach to philosophical ethics and considers the implications for engineering ethics and research ethics.

Many philosophers writing ethics in the period of the Enlightenment and some rationalist philosophers in the preceding century thought it important to give answers to the question: "What does reason tell us that ethics is all about?"

The answers they gave were notoriously different, ranging not only from "Ethics is about producing consequences and the number of individuals who experience those consequences" to the "Ethics is about acting from the motive to do one's duty (or obeying the Categorical Imperative[8])" and "Agreeing to accept those restrictions that one would want others to accept." They may even include "respecting others human or natural rights, and the derivative rights that derive from agreements (although it is less clear that John Locke thought reason dictates what ethics is all about and modern rights theory may rest on some distortion of Locke). It is notable that these answers shared the common assumption that the business of ethics was to evaluate acts.

That these theories are sometimes taken to have some relevance for areas of practical and professional ethics largely rests on a misunderstanding of the function of Enlightenment ethical theory. That misunderstanding is the simplistic belief that consequentialists say that in ethically evaluating acts, we should consider consequences, deontologists say we should consider duties and contractarians say we should consider agreements. Enlightenment ethical theory is not so simple-minded or so practical. Richard Brandt's Rule Utilitarianism should have served notice that utilitarianism as an ethical theory concerns the supposed essence of ethics (which Reason supposedly reveals), which is about procuring the best consequences, and is quite compatible with saying that the best consequences result when agents follow moral rules.

The direction of modern philosophy and in particular its inheritance of Enlightenment assumptions about the ethical content that abstract reasoning might reveal was implicitly or explicitly criticized in essays by several distinguished 20th Century philosophers beginning in the middle of the century, most of whom cited Aristotle as taking a more congenial approach to ethical theory. After 1980, other distinguished philosophers wrote books that sought to show what was wrong with Enlightenment ethics or the modern moral philosophy that inherited from it.

Prominent among the first group of essays were Stuart Hampshire's 1949 article, "Fallacies in Moral Philosophy," Elizabeth Anscombe's 1958 article, "Modern Moral Philosophy." Later, in 1971, Edmund Pincoffs published, "Quandary Ethics."

Prominent in the philosophical literature after 1980 are books by Alasdair MacIntyre, the late Bernard Williams, and Annette Baier. Alasdair MacIntyre's *After Virtue: a Study in moral theory* appeared in 1981, Bernard Williams' *Ethics and the Limits of Philosophy* appeared in 1985, Annette Baier's, *Moral Prejudices* did not appear until 1994, but that work collected many of her essays from earlier years and it is notable that in the year after Williams' *Ethics and the Limits of Philosophy* appeared, she delivered a symposium paper to the American Philosophical Association titled "Extending the Limits of Moral Theory" in which she argues against the abstractness of much recent philosophical ethics and the irrelevance of that theory to any practice including the teaching of the theorist's own classes in moral philosophy. These three philosophers differ on some significant points that I now briefly summarize.

In *After Virtue,* Alasdair MacIntyre argues that Enlightenment theory rests on a mistaken project, viz, to found ethics on reason alone. When he wrote *After Virtue* MacIntyre was best described as an Aristotelean, although he began as a Marxist and is now a Thomist of sorts.

During the 1970s, he was involved in discussions of medical ethics and that experience with the attempts to apply Enlightenment theory to problems of practical and professional ethics led him to write his 1984 essay, "Does Applied Ethics Rest on a Mistake?". The central error he identifies is the error of believing that moral rules (or the higher order ones, termed "principles") can be learned apart for a domain of application. This applies to those principles, such as the principal that one should achieve the greatest good for the greatest number, that are the hallmark of one Enlightenment ethical theory or another. MacIntyre identifies certain variants within Enlightenment Ethical Theory: "Kantian, utilitarian, contractarian, Kantian-cum-utilitarian, Kantian-cum-contractarian and so on." He might have added "virtue ethics" if that is understood as the (simplistic) view that consideration of what produces/demonstrates virtue is the basis for ethical standards. Although MacIntyre's views are often described as "virtue ethics," his arguments do not urge consideration of virtues and vices, rather than harms and benefits, duties, or (ideal) agreements, but criticize the way of

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[8] "Act only according to that maxim by which you can at the same time will that it should become a universal law," which means to act so that one (the rational agent) could consistently make it a universal moral rule to act that way."

doing philosophical ethics that has dominated in Anglo-American countries.

Although he criticizes MacIntyre for faulting Enlightenment theory for rationalist errors that Williams finds also in Plato, Bernard Williams nonetheless argues that Enlightenment ethical theory and its intellectual children do not fit modern life and, that ancient philosophy fits it better. Like Anscombe and unlike MacIntyre, Williams is somewhat more critical of the modern developments of Enlightenment theory than of the original Enlightenment project, but like MacIntyre and Baier, Williams criticizes it for its failure to understand practice, the social and historical context, and particulars. He says,

> [Most of modern philosophy] is too much and too unknowingly caught up in [the modern world], unreflectively appealing to administrative ideas of rationality. In other ways, notably in its more Kantian forms, it is not involved enough; it is governed by a dream of a community of reason that is too far removed....from social and historical reality and from any concrete sense of a particular ethical life —farther removed from those things, in some ways, than the religion it replaced. These various versions of moral philosophy share a false image of how reflection is related to practice, an image of theories in terms of which they uselessly elaborate their differences from one another.[9]

Williams does explicitly embrace the modern values of freedom and social justice, unlike MacIntyre who is often critical of modern life and questions the modern conceptions, such as that of justice, a point nicely reflected in his 1988 book, Whose Justice? Which Rationality? Unfortunately, Williams called the Enlightenment approach to ethics “ethical theory”, thus making it easy for those embracing Enlightenment theories to dismiss his and the other arguments I summarize as ‘anti-theoretical,’ notwithstanding the clear evidence of MacIntyre’s title, After Virtue: a Study in Moral Theory.

Like Williams and unlike MacIntyre, Annette Baier is dismissive of religion, but she is less skeptical about what philosophical might become than Williams. Unlike either man, Baier is both a Hume scholar and a (late) feminist who acknowledges a debt to Hannah Arendt. In the U.S. Baier led the new attention to trust and trustworthiness in moral theory and practical and professional ethics. Baier is particularly skeptical of modern rights theory and turns her wit against many of the pompous language of 5 After Virtue: a Study in Moral Theory Anglo-American practical ethics, especially the concern with “dignity.” Like MacIntyre, Baier argues that ethics is the product of a cultural group and reflects its accumulated experience in particular conditions, and that ethics is embodied in practices and traditions, not only in stated rules and principles. Her view, similar to MacIntyre’s in “Does Applied Ethics rest on a Mistake?” is that philosopher can assist a cultural group’s reflection, but the ethical judgments of philosophers or philosophical schools of thought are not privileged as Enlightenment ethics had thought.

I will then briefly describe practical and professional ethics

Practical and Professional Ethics

Practical Ethics examples: Parenting/friendship- Responsibility for aspects of child’s/friend’s well-being

No mastery of specialized knowledge required to become a parent or a friend

Professions, (vs. other occupations) require

- Mastery of specialized knowledge
- Address (responsibility for) major aspects of others’ well-being

Are research investigators professionals? Are philosophers?

Therefore: Professional ethics centers on marshalling expert knowledge to address problems of others’ well-being

No mastery of specialized knowledge required to become a parent or a friend

Professions, (vs. other occupations) require

- Mastery of specialized knowledge
- Address (responsibility for) major aspects of others’ well-being

Are research investigators professionals? Are philosophers?

Therefore: Professional ethics centers on marshalling expert knowledge to address problems of others’ well-being

Approaches to Practical & Professional Ethics

- Applied ethics judges acts on the basis of conformity with the central principle of some Rationalist/Enlightenment approach
    - Produce the greatest good for greatest number - Utilitarian
    - Treat persons as ends, not as means only - Deontological
    - Are restricted as one would want others to be restricted - Contractarian
- (Philosophical Approaches to) Practical Ethics
    - Responsibility/Trustworthiness Approach: Takes moral responsibilities as central. Responsibilities are for outcomes and one must figure out what acts might best achieve them
    - Thomist and casuistic approaches
    - . . . .

Ethical Guidelines and Traditions

Reflect the Collective Experience of Practitioners – “Testimonies”

- Experience of ethically significant problems–and moral pitfalls– that arise in practice
- Experience of measures that help avoid the pitfalls

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[9] Bernard Williams, 1985. *Ethics and the Limits of Philosophy,* 197-198.

Rules of behavior do require or forbid some acts - Medicine: Do not seduce one's patients, Engineering: not accept gifts over a certain value.

Give guidance about the priorities among one's responsibilities and other requirements - Patient health is the physician's central concern, Public health and safety is of paramount concern in engineering.

Statements given in ethical codes and guidelines (and testimonies) are generally "living" documents, that is, they grow with the experience of the community or profession.

Responsibilities approach

Responsibilities arise out of human relationships

Thus, relationships are essential to being a moral person

Recognizes the importance of moral traditions and practices

(Human) rights are the claims against strangers or institutions that must be honored if one is to fulfill one's responsibilities. (Similarly, obligations)

Adequate to express deliberation (about what to do), as more than judging (what was done)

Senses of Responsibility

Responsibility in the causal sense - "The storm was responsible for (i.e., caused) three deaths."- need not provide a basis for assigning moral blame.

Responsibility in the sense of accountability, specifies to whom a rational agent answers. "The President is responsible (i.e., accountable) to the Trustees."

Responsibility in the prospective sense is a charge to achieve specified ends. "Research investigators are responsible for the integrity of the research record." Note that criteria for being a responsible person = those for being a trustworthy person (so responsibility approach accommodates philosophical work on trust

Toward an Epistemology of Engineering

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Keywords
Constructivism, design, critical discussion, engineering, epistemology, methodology, ontology, philosophy of knowledge, positivism, transdisciplinarity, wicked problems.

1. INTRODUCTION

Although engineering is considered, today, as clearly distinct from science, the predominance of the components of basic science in the education of engineers implicitly contributes to convey the idea that engineering is, in essence, little more than the mere application of the exact and natural sciences to the reality of practice. To help challenge this vision and contribute to a reflection on the epistemology of engineering, we propose a model where engineering is seen as developing in four dimensions linked in a transdisciplinary relationship. We then articulate this model with the four key questions of the philosophy of knowledge [1][2] to clarify the nature of this relationship and illuminate some distinctive attributes of engineering knowledge.

2. FOUR DIMENSIONS

In the discussion of engineering knowledge it is helpful to think of engineering as comprising four major dimensions (Fig. 1): the dimensions of the basic sciences, of the social sciences, of design, and of practical accomplishment. This lets us think of the engineer as a professional who combines, in variable proportions, the qualities of a scientist, a sociologist, a designer, and a doer.

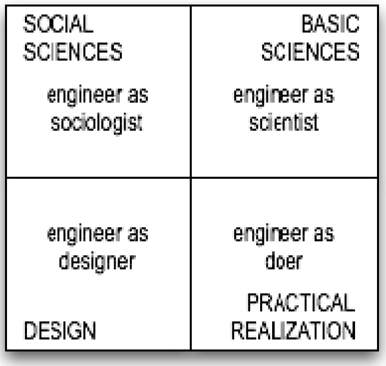

Fig. 1 – The four dimensions of engineering.

The dimension inspired by the basic sciences views engineering as the application of the natural and exact sciences, stressing the values of logics and rigour, and seeing knowledge as produced through analysis and experimentation. Research is the preferred *modus operandi* of this dimension, where the discovery of first principles is seen as the activity leading to higher recognition.

The social dimension of engineering sees engineers not just as technologists, but also as social experts, in their ability to recognize the eminently social nature of the world they act upon and the social complexity of the teams they belong to. The creation of social and economic value and the belief in the satisfaction of end users emerge as central values in this dimension of engineering.

The design dimension sees engineering as the art of design. It values systems thinking much more than the analytical thinking that characterizes traditional science. Its practice is founded on holistic, contextual, and integrated visions of the world, rather than on partial visions. Typical values of this dimension include exploring alternatives and compromising. In this dimension, which resorts frequently to non-scientific forms of thinking, the key decisions are often based on incomplete knowledge and intuition, as well as on personal and collective experiences.

The fourth mode views engineering as the art of getting things done, valuing the ability to change the world and overcoming complexity with flexibility and perseverance. It corresponds to the art of the *homo faber*, in its purest expression, and to the ability to tuck up one's sleeves and get down to the nitty-gritty. In this dimension, the completed job, which stands before the world, leads to higher recognition.

3. A TRANSDISCIPLINARY APPROACH

If we look at the aggregation of the four dimensions as an exercise in transdiscipliarity, as defined by Gibbons et al. [3], we may see engineering as resulting from the mutual interpenetration of the epistemologies of the four dimensions in the context of disturbances that shake up the corresponding systems of knowledge production. This agrees with the understanding of transdisciplinarity as the continuous linking and re-linking, in specific clusterings and configurations, of knowledge that is brought together on a temporary basis in specific contexts of application, which makes it strongly oriented to, and driven by, problem-solving [3].

If we now take the epistemological traditions of each one of the four dimensions, we are led to acknowledge a likely positivist contribution from the epistemologies of the basic sciences. Identically positivist dominance can generally be recognized in the epistemological dimension of the social sciences, although the adoption of constructivist approaches in this dimension is gaining ground. Design brings to our epistemological cluster the most challenging contribution, as we will briefly discuss in the next section. Finally, although the epistemology of practical realization tends to be less contemplated in the literature, its constructivist nature is strongly supported by the tradition of pragmatist philosophers, the works of Schön [4] and his followers, and the contributions by Mintzberg [5], Ciborra [6] and many others to the theorization of crafting and bricolage.

4. EPISTEMOLOGY OF DESIGN

The epistemology of design has been suffering a dramatic evolution since the positivist scientization of design introduced by the 'modern movement of design', in the early 1920s. It then witnessed the backlash of the 1970s, against the scienceinspired design methodologies and the claim that the epistemology of science was in disarray and had little to offer to an epistemology of design, that there were forms of knowledge peculiar to the awareness and ability of the designer, and that we should rather concentrate on the ‘designerly’ ways of knowing, thinking and acting [7]. More recently, the troubled relationship between science and design seems to have started to head toward reconciliation, with the recognition that the epistemology of design is, indeed, different, and has much to contribute to a renewed epistemology of science [8].

This view, which expresses the transdisciplinary linking and relinking fields that are closely related, incorporates the ability to take into account ‘wicked problems’. ‘Wicked problems’ are problems that, because of their complexity and close interdependence with social and organizational factors, cannot be formulated [9]. To deal with wicked problems, which are becoming increasingly common in engineering, in spite of the fact that they cannot be handled through traditional scientific approaches, the process of solving a problem becomes identical with the process of understanding its nature, so that problem understanding and problem resolution are concomitant, with the information needed to understand the problem depending on the designer’s ideas for solving it.

Important contributions to this debate have been developing recently in the information systems field, where the evolution of systems design has been described as incorporating four categories: design as functional analysis, design as problemsolving, design as problem-setting, and design as emergent evolutionary learning [10].

Design as functional analysis assumes requirements to be fully available at the outset, so that the designer just needs to analyze the problem and deductively proceed to the solution, following a path closely inspired by the traditional basic sciences [8].

Design as problem-solving resolves complex, namely organizational, problems by simplifying them to a level where they can still satisfy a minimal set of criteria leading to their rational solution [8]. This category of design is inspired by Herbert Simon’s concept of “bounded rationality” [11], which reflects an epistemological standing closer to some popular visions of the social sciences.

Design as problem-setting views design as a systemic activity requiring the discovery and possible negotiation of unstated goals, implications, and criteria before a problem can be formulated and, subsequently, solved [8]. By accepting the framing of problems in terms of their context, before they can be solved, this vision of design takes a phenomenological approach that expresses a constructivist epistemology.

Design as emergent, evolutionary, learning sees design as the convergence of problem and solution in an emergent process of learning about a situation and then planning short-term partial goals that emerge as the process progresses [10][12]. Aspects of the solution are thus explored in conjunction with aspects of problem understanding: not only the problem is unclear at the start of the process, but the goals of the design are also illdefined 10]. Design, emerging, in this case, in multiple circular references, linking problem formulation and problem solution, explicitly emphasizes the constructivist nature of this approach.

5. EPISTEMOLOGY OF ENGINEERING

Taking as a reference the proposed four-dimensional model and the epistemology of design briefly discussed in the previous section, the remainder of the talk analyses the epistemology of engineering in light of the four key questions of the philosophy of knowledge [1][2]: the ontological, the epistemological, the methodological, and the axiological questions. For the case of engineering, the ontological question inquires about *what reality can engineering know*, the epistemological question looks into *what is engineering knowledge*, the methodological question asks *how can engineering knowledge be built*, and the axiological question (which includes the ethical question), inquires about *the worth and value of engineering knowledge*.

The talk answers these questions in the context of the proposed model. It also stresses the key distinctive features of engineering knowledge that emerge from the strong presence of a design dimension. This includes the importance attached to abductive reasoning and the acceptance of courses of action that seize upon chance information, adopt capricious ideas, and provoke creative leaps that seem to go against traditional scientific rigour [8]. Popper’s concept of ‘critical discussion’ [13] will be used to illustrate how the epistemology of engineering can derive final and verifiable rigour from such apparently unsystematic, imprecise, and even random, intermediate steps.

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Hydraulic engineering reflected in the humanities

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Keywords

Philosophy, hydraulic engineering, culture, worldviews, rivers, nature, cultural studies

1. Introduction

At this workshop I would like to place three different spotlights on reflections in the field of hydraulic engineering. At first I present some philosophical thoughts about technology and culture in general. The second aspect leads us from today's hydraulic engineering and existing buildings at rivers back into history, but not into the history of hydraulic engineering but that of the ideas of our occidental culture. I demonstrate several close links between the practice of hydraulic engineering (in the last 50 years) and our cultural roots. The third spot highlights the future of hydraulic engineering. Based on some lacks of today's hydraulic engineering in Germany I'll offer four suggestions for a future practice: a reasonable hydraulic engineering, a more hermeneutical one, a culture-sensitive hydraulic engineering, with always perceptible buildings and technological constructions. In each spot examples of the practise of hydraulic engineering will be given.

2. TECHNOLOGY – A CULTURAL APPROACH

I start this approach against the background of a contemporary understanding of "culture", where the difference between nature and culture is no longer constitutive but just the simultaneous existence of three elements: collectivity, communication and convention [1]. In this understanding of culture, technology in a wider sense can be seen as a material, institutional and mental product under the conditions of culture.

Considering this it becomes clear that technology is not only a rational approach following aimed facts ("erstrebte Sachverhalte" [2]) or exclusively following social general conditions (e.g. economical ones), but also and first of all is guided by cultural certainties ("Gewissheiten" [3]) which are mostly unconscious and hidden in our cultural background. So design and production of technology appear not only as technical acting, but also as an a-rational, unconscious becoming, as technical behaviour.

Technology – even large-scale technology like hydraulic engineering – is reflecting to a high degree the certainties of a society, and namely not only in the form of obtained knowledge but also in the form of collectively shared imaginations and unscrutinised convictions. Following Adorno's statement that art is the antithesis of society [4], (large-scale) technology can be seen as thesis of society [5].

3. TWO STYLES OF HYDRAULIC ENGINEERING AND THEIR CULTURAL ROOTS

In this chapter I demonstrate considerable differences between two ideal styles (or 'cultures') of hydraulic engineering referring to our cultural roots. Clear examples for the first style which I call "Massivwasserbau" ("massive hydraulic engineering") [5] can be found in Germany in the 1950s, when (the channels of) many rivers and brooks where 'corrected' with a lot of concrete. The second one is the currently preferred style of "Naturnaher Wasserbau" ("ecological" or "near-natural hydraulic engineering"). Generally in both styles you can find (via interpretation) ideas, concepts and splinters of worldviews as motives,, which can be located in our occidental history – even back to the antique.[1]

For example you can regard the massive style as a continuation of the historical line of Descartes, Bacon, materialism and the dominance of economy; the near-natural style as a continuation of the contrary ideas of Rousseau, romanticism and the ecological movement.

In the hydraulic engineering's worldview of the massive style "nature" is regarded as something outside, external, apart of man, technology and 'culture'. Nature is seen as opposite and opponent and as an object to be used. In the view of the near-natural style you can find "nature" as something positive, to aim for, as a shining example. Man is recognizing himself – within his whole cultural sphere – as interweaved in an ecological union of all natural things. He recognizes himself as a part of an all-embracing "eco-nature". Accordingly this eco-nature is grasped from the perspective of the participant and can therefore never be completely recognizable for man. That means also that nature is – in contrast to the massive style – keeping some secrets and miracles for ever.

The near-natural style represents ideas of a perfect, a creative and moving nature ("natura naturans") in contrast to the massive style, where you find a nature full of mistakes ("natura lacta") and man as (the) one big mover and creator ("natura naturata"). On the one hand you can find platonic-Christian views, on the other, in the near-natural style, strongly aristotelic ideas. At the massive style man sees itself as top and crown of the creation, in the near-natural style man appears more as an ecological "Mängelwesen" [6], an insufficient ecological being that mostly hinders nature by evolving, or at best can support it.

The understanding of "technology" in both styles is corresponding with the respective understanding of nature. In the context of the massive style you find a mechanistic understanding of technology (and hydraulic engineering) in tradition of the machina-mundi-motive. In the near-natural style you find a complex understanding of technology in the line of the systema-mundi-motive. Rivers often are described – in contrast to the massive style – as a kind of living being or individual.

4. SUGGESTIONS FOR A FUTURE PRACTICE

The first suggestion is to practice hydraulic engineering in the most reasonable way. For that purpose a 'holistic' understanding of the world – or rather the hydraulic engineerings' world with its rivers, landscapes, technology, etc. – by hand, head and heart is required and not only one by mind. Moreover a moderate and reasonable dealing with nature and self-image is necessary.[2] Following this it might be appropriate in some cases not to realize given technological possibilities. Now and then the achievement of hydraulic engineering is lying in the renunciation of technology. Such a reasonable and moderate hydraulic engineering thoroughly follows an emancipatory aim, not – like the massive hydraulic engineering did – to free man from the shackles of nature but further more to preserve man from the restricting consequences of his own careless doings.

The second suggestion is that hydraulic engineering should be practiced not less analytically but more hermeneutically. A hermeneutic hydraulic engineering could bring two essential aspects of hermeneutics into technical acting: dialogue and distance. The (planning) hydraulic engineer could come to a deeper understanding of the given situation at the river, the landscape, etc. by getting into dialogue with them. On the other hand the engineer could get distance to the process of cognition and with it also distance to his working. With the back stepping of the results performing subject (the engineer) appropriate and reflected technological solutions would be enabled.

Hydraulic engineering today is determined by the dealing with nature and therefore the knowledge of natural sciences. In future more attention should be given to the cultural side. Just like the Massivwasserbau has changed from a mechanistic view into an ecological, it is now important to develop a kind of sensitivity and sensorium for cultural aspects of hydraulic engineering and the world changed by it. The importance increases the more 'culture' and technification are getting ahead.

The fourth point is that technology as artefact should be perceptible for everyone. Technology should be transparent, because technology – and most large-scale technologies like hydraulic engineering – as thesis of society has to be discussed if necessary. Technology as artefact is witnessing our dealing with our "Umwelt" ("environment"), "Mitwelt" and "Nachwelt" ("posterity"). Technology shows our values, preferences and imaginations. It is always to be asked if this dealing is still appropriate, if the thesis is collectively carried on. Technology should serve us as a mirror of our way to live and our self-image. Only through the realizing contact to technology, to its shape, function and content, we can decide with which technologies we want to live and surround us and with which ones not.

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1. I found these differences in all kind of cultural sources of hydraulic engineering like: laws, handbooks, the shape and function of buildings, curriculums, interviews – of the 1950s and today.

2. In history (of ideas and of hydraulic engineering) both have weaved between over- and underestimation.

Textual Research on Professional Awareness of Ethics in up-to-date Constitutions of Chinese (mainland) Engineering Public Organizations

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Objective: Mr. Michael Davis asked an interesting question: Is there a profession of engineering in China mainland? That means that do Chinese engineering public organizations openly serve a moral ideal in a morally-permissible way beyond what law, market, morality, and public opinion would otherwise require, in written form or not.[1] The purpose of this presentation is to examine the professional ethical awareness in constitutions of engineering public organizations.

Method: We pay important attention to those engineering codes of ethics as the central formulation of the ethical obligations of engineers, and collected 46 constitutions of nationwide engineering public organization in China up-to-date, and the constitution and scientific moral code of Chinese Academy of Engineering. Based on these documents, we analyzed professional ethical awareness of Chinese engineering collectivity.

Findings and conclusion:

1. Chinese Academy of Engineering (CAE), as the highest level honorary and consultative academic organization in Chinese engineering technological world, was set up in 1994. CAE stipulated academicians' scientific moral codes in 1998, some self-discipline regulations of academicians' scientific moral codes in 2001. The scientific moral codes and self-discipline regulations came on in response to allegations of scientific misconduct. Both in CAE constitutions and codes, we can only find obligations to science not to engineering practice, e.g. to enhance scientific spirits, to spread abroad scientific thoughts, to sparkplug advanced scientific culture, to maintain dignity of scientific morality, and to popularize scientific and technological knowledge. The content of codes and regulations matches the name of them, scientific moral codes, not engineering codes of ethics. They dealt with authorship, intellectual property, peer review, academic critics, commercial propaganda, fighting against pseudoscience, superstition, etc.
2. There are 64 nationwide societies related to engineering in Chinese mainland now. They are public organizations belonged to China Association for Science and Technology. There are no codes of ethics for these public organizations, except for China Computer Federation. The codes of ethics of CCF are also scientific moral codes, not engineering professional codes of ethics. They treated of respecting to intellectual property, deferring to facts, evaluating works objectively, keeping impartiality in peer review.
3. We have collected 46 constitutions of them. 38 copies were put out after 2001, 7 copies was put out during 1999 to 2001, and one copy could not be found its date. All of them were stipulated or revised after 1998, according the model text of constitution of public organizations set down by Chinese Ministry of Civil Administration. For instance, the purposes of those public organizations, which their consciousness of ethics are reflected in, homoplastically relate to abiding by Constitution and laws of China, promoting the development of sciences and technologies, serving economic construction (only considering the positive impacts of engineering), enhancing national and international academic communion, insisting on democracy in managing organizations, etc.
4. World Federation of Engineering Organizations (WFEO), under UNESCO, formulated a model code of engineering ethics for its member organizations, and reversed it in 2001. The model code of ethics presented herein expresses the expectations of engineers and society in discriminating engineers' professional responsibilities. However, the model code of engineering ethics does not affect the constitutions at all, which were put forward by 38 public engineering organizations after 2001.
5. Even engineering disasters arousing public attention have not awoke leaders of those engineering societies to upgrade ethical standard of engineering professional behavior. We can not find any change in the purpose of China National Coal Association about safety and health of mineworkers after so many mine disasters. Foods safety and health are not mentioned in the purpose of China Cereals and Oils Association, environment protection is almost neglected in the purpose of China Paper Making Association, energy conservation is not in The Architectural Society of China, etc.
6. Chinese engineering organizations lack of legible and comprehensive cognition about ethical responsibility of engineering, and a moral ideal in a morally-permissible way beyond what law, market, morality, and public opinion would otherwise require in their written constitutions and in their minds up-to-date, though ethical obligations of engineering have become important part of qualification standard for Chinese registered engineers. Both CAE and engineering public

organizations take themselves as academic groups not as societies of professional engineers.

7. If we could say that Chinese government, science community and public have attached importance to scientific research integrity/ethics to some extent, then we must say that there is more work to do about ethics of engineering. Revising the texts of constitutions and formulating codes of ethics are prime steps, reforming the systems and improving engineering education are also necessary steps.

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Hitches & Prospects: Outlining Portuguese Encounters of Philosophy, Sociology and Anthropology with Engineering and Technology.

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1. Introduction to Portuguese Engineering and Technology R&D and Education Panorama.

In the past twenty years, the Portuguese Engineering and Technology R&D and education systems carried out substantial efforts to extend and sustain higher levels of competences, knowledge and innovation. Amongst major accomplishments, it is important to draw attention to the growth of highly-qualified graduate experts along with the reorganization of University and Polytechnic structures; the proliferation of new research areas with the sprouting of academic spin-off entrepreneurships and research business agents; an adoption of triple-helix models as links between academia, industry and government, and the materialization of public and private partnerships; or the increased assembly of national consortiums and subsequent participations in international networks. This panorama is attached to the European integration in 1986, through the import of external discourses and agendas on innovation. But by the same token, it should also be framed as an amplified effect of internal debates on the design and execution of national long-term science and technology policies, with the intent of allocating resources for a knowledge-based economy.

This panorama, however, still presents extensive shortcomings, in a traditional semiperipheral zone, typified by an enduring undersized dimension with insufficient logistic or human recourses. And such perception is either confirmed regularly through interpretations of statistics like the prevalent obstacles to innovation recognized by enterprises (scarce information on new markets and technologies; shortage of graduate researchers in business and industry; and difficulties in establishing cooperative academic partnerships [1]); or through the existence of trends such as a low flow of engineering and science graduates into employment markets (percentage of labor force in 1996 was 0.03%, i.e. 25% of EU average [2]).

Nevertheless, according to several national [3] [4] and international views [5] [6], deficient collaborations between engineering, human and social sciences; lack of technical research powered by non-technical issues as social and political values; or deficient channels for public diffusion of science and technology; are now similarly emerging as primary limitations of the Portuguese context. These views mainly report to a scenario where, as an example, we should point out that the largest Portuguese Engineering School, at the IST - Technical University of Lisbon (data referring to Civil, Mining, Mechanical, Chemical and Electro-technical Engineering), only had a 9% share for humanities and social sciences course modules in 2000/2001, in comparison to 19% in the year of 1941, or even 20% in 1912/1913 [7]. Whereas they are also strongly attached to the acknowledgment of this same context as one where Philosophy, Sociology and Anthropology graduate or undergraduate courses, are hardly ever intertwined with technical education or research [8].

2. Adverse Disarticulations and Some Examples of Excellence in Engineering and Technological Fields.

Portuguese interactions of Engineering and Technological fields on one side, with Philosophy, Sociology and Anthropology, on the other side, have been essentially entangled in rigid and conservative separations, while administered by meager symbolic connections. This disarticulation has been contrary to developments within each area in the last two decades, and contrary to efforts towards joint epistemological notions of technical phenomenon, as increasingly required internationally by debate and professional associations, or even desired by yet a few of our technical and social researchers.

Technical sectors have stayed away from reflexive trends, and consequentially amiss in internal views about the ontology of their actions and culture [9]. They are still reproducing enclosed and self-sustained standards, while showing what is yet to be accomplished regarding comprehensive analyses on technological knowledge and practices [10] [11], or their applied models and explanation modes [12] [13]. As for humanities and social sciences, difficulties mainly take place when these approaches attempt to engage in informed discussions on technological processes and artifacts, without listing abstract considerations or staying inside instrumental analytics [14], that usually fall outside the major research and funding frameworks.

Nevertheless, observing a small cluster of Engineering university units and governmental agencies, as also some leading industries and business, we can trace a movement interested in abridging this divide. Amongst such tendency, we need to mention as academic examples IN+ / Center for Innovation, Technology and Policy Research of IST, with equity initiatives centered on energy and materials efficiency, or responsible innovation policies for science quality; and NDS / Group of Design for Sustainability of IADE-Lisbon, which pursues ethical and deontological interests, for social and environmental sustainabilities, or inclusive and open design projects. With reference to governmental agencies, INETI / National Institute of Engineering, Technology and Innovation, is relevant due to its concerns with value-laden aspects of technology; as well as LNEC / State Laboratory of Civil Engineering, fostering contextual and local inclusions of social public concerns in their technical projects. Considering business and industries, YDreams deserves a reference with interdisciplinary expert teams, working on virtual educational environments and public interfaces for citizens' participation; while SelfEnergy also justifies attention, as a spin-off of UAtec / Technology Transfer Unity of the University of Aveiro, running projects for the local production of renewable energies, their increased energetic efficiencies, and their social affordability.

But beyond these notable unilateral cases, the prevailing isolation of both technical and social territories should not be overlooked, as it undermines potential convergences between each field's resources. Overall, the Portuguese situation may be characterized by striking deficiencies in constructing common strategies that would be able to avoid such an asymmetrical ensemble of centers, programs or projects. It is still hard to manage interdisciplinary platforms that could move us into ground areas where Philosophy, Sociology, and Anthropology meet and discuss with Engineering and Technology.

3. Looking Towards Alternative Pathways in the Territories of Humanities and Social Sciences.

In relation to Humanities and Social Sciences, with the exception of a few researchers and small projects, linkages to the other aisle have been even more limited and superficial. It should be made clear that, to a certain extent, their major conceptual and empirical contributes enlarged and established most interpretations of technology that allowed the construction of a few public engaging and sustainable technology policies. But their focal projects and outputs resulted more than often from observational procedures on representations and impacts of the technological in the social arena. And when escaping this trend, they commonly connected themselves to simple historical reviews or sociographic backdrop checks of Engineering and Technological education and research. In doing so, they have constrained potential relations of the social with the technological present in both research and education fields, while concomitantly establishing their stationary views as a major standard for funding.

It is within this context that we run into the need of new guidelines for assembling fundamental and applied Philosophical, Sociological and Anthropological research and education plans, with more active participations and interventions on the technical process. Portuguese communities in Social Sciences and Humanities have been opening themselves to boundary piercings regarding various other questions, and this is quite an appropriate time for advancing in such endeavor.

Between March and June 2007 we took a first step by organizing a series of four international lectures, with the label *"Other Technical Worlds / Our Modern Worlds"*, in the Department of Sociology of ISCTE / Lisbon University Institute. With this event we were able to attract social and human scientists engaged in technical spheres, but even more, create a different focus for engineers and other technological practitioners concerned with social, philosophical, or ethical dimensions of their work. Since May 2008 we have been drawing upon these lectures and some other subsequent initiatives, to institute a permanent interdisciplinary laboratory / incubator of social ideas, technological constructions and entrepreneurship, in CIES / Center for Research and Studies in Sociology – ISCTE.

We foresee our approach as a substantial alternative advancement to common national platforms that human and social researchers have shared until now with technological agents. The laboratory / incubator's guiding principles revolve around such a basic point as the grouping of usually scattered individual and collective agents, while inevitably linking forms of knowledge traditionally detached in Portuguese education and R&D context. But we equally envision it as an arena where technical and social agents, already operating in interdisciplinary settings, will find support for new field crossings.

At the moment, we are working towards collaborative international and national workgroups with social and technical selected partners, for running both reflections and executions in the technical stages of invention, design, production, distribution and use. Our general aim is to focus on technological objects and systems based on inclusive, open and democratic design, in addition to promoting values as precaution, sustainability, public participation, convivial and fair use, as well as deference for local needs [15] [16] [17] [18] [19].

This project has been initially shaped by insights of the integrated teaching and research conducted by Alain Gras [20] and his team at CETCoPra, of Université Paris-1 Panthéon-Sorbonne; but its major configuration have been lastly defined by privileged observations of the work accomplished by David Hess [21] and Langdon Winner [22] in the PDI / Product, Design & Innovation program and its Interdisciplinary Studios, at the Department of STS in Rensselaer Polytechnic Institute. Additionally, secondary and online reviews of other experiences have also been considered, regarding centers like 3TU / Center for Ethics and Technology, at Eindhoven, Twente and Delft; or INCITE / Incubator for Critical Inquiry into Technology and Ethnography, at Sociology Department of Goldsmiths College.

In our presentation we will address in greater depth the hitches and prospects of setting up this type of project, within a semiperipheral context strongly characterized by irregular connections between the social and technical worlds. The central point of discussion will be on the Portuguese education and R&D panorama. But as corollary we will equally explore some of the pathways embraced until now, regarding our applied and localized efforts to develop encounters and collaborative actions between agents in Philosophy, Sociology, and Anthropology, and those inside Engineering and Technology.

4. Acknowledgements.

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‘Steamy Encounters’: Bodies & Minds between Explosions & Automation

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In this paper we introduce to some philosophical and historiographical considerations regarding engineering, which arise from bringing together two historical literatures: a history of minds, self-regulatory, feedback, automatic mechanisms, and, a history of bodies, killed or mutilated by steam engine explosions during the long 19th century. In doing so, we contrast some engineering rhetoric on automation, i.e. technical self-regulation, to a synchronic historical reality of control disasters. This is further associated to the dissociation of minds and bodies in the capitalist division of labor, of heads from hands, with the first being presented as more important than the second in social terms. Finally, while feedback has been related to a liberal market-type of self-regulation, the historical consideration of state interventions for the prevention of explosions related to feedback mechanisms point to the parallel development of the capitalist state as indispensable for the capitalist market.

The bright side of the long nineteenth century begins with Watt’s introduction on the steam engine of the governor, the *par excellence* mechanical control machine and closed loop feedback mechanism. Its dark side begins and ends with major control disasters. It begins with a great number of steam boiler explosions only to close with the emergence of another category of fatal accidents, flywheel explosions. These control related disasters exceeded, in terms of fatalities and of attracting theoretical consideration, all other steam engine related accidents. Boiler explosions met their peak during the period of the gradual replacement of the low pressure by the high pressure engine, round between the 1820s and the 1870s, although such events kept occurring in low pressure engines as well in the following period were steam remained in use in the twentieth century (e.g. in locomotives). Flywheel explosions, as it may be inferred from the discussions in the technical literature, became a matter of concern during the late nineteenth and into the first decade of the twentieth century. They have emerged along with the pressing demand for ever higher speeds that were especially needed in the production of electrical power.

A great number of steam boiler explosions had been haunting steam engines of all kinds, from Victorian Britain to Ante- and Postbellum America, France and Germany. Here the first two cases have been extensively addressed. Occasions of bursting boilers were more than often lethal, turning human bodies into scorched flesh and characteristically were a scoop for reporters. Thus, despite the presence of feedback mechanisms as, supposedly, artificial minds, steam engine explosions kept injuring or even killing human bodies. For the most part of the long nineteenth century, explosions were a fright for the masses and a problem for state authorities and the relevant civilian manufacturers and proprietors, whose interests were at stake. Typical, were experiments carried out by committees of engineers and state delegations set up so as to shed light into the causes of steam boat explosions. It was through the laborious work of committees of this kind that the profession of the engineer was constituted and embedded with its accompanying technical authority and expertise. The reconfiguration of power relations that took place during the institutional formation of engineering societies rearranged the relations between minds, bodies and machines, notably by elevating engineering labor, i.e. computation as by its own means providing for technical self-regulation, while downplaying manual labor.

To start with, efforts concentrated on what was going on inside the generator, i.e. the steam engine boiler. The pursuit was for a uniform and steady production of steam which had huge impacts on the uniform and steady working of the other part of the engine assemblage, the motor. In studying how the problem of steam boilers explosions was approached from the relevant discourses, what is remarkable is that the rhetoric of automation prevails even if automatic mechanisms appear to be related to the causes of explosions, either by themselves or in “human-machine” dis-functional couplings. Boiler explosions were thought as able to be solved by means of constructing a strong boiler, furnished with a minimum of necessary and well constructed self regulating devices while assuring that the engine-man and the fireman would constantly and uninterruptedly watch out for any irregularities. Through the discussions over boiler explosions we may infer that engineers were maintaining that if production of steam was made uniform then it would render equally uniform the engine’s motion. By the end of the nineteenth century steam boiler explosions have been shown to have declined. When explosions ceased to manifest themselves in the boilers the problem was in turn manifested on the other part of the steam engine assemblage, the motor. With increasing speeds, the governor was proven unable to maintain the dynamic equilibrium between the boiler and the motor. As with the safety-valve in the case of steam boiler explosions, the governor’s inability to regulate was ‘unraveled’ by the engineers discourses, while at the same time the attendant of the engine similarly becomes one of the causes of the accidents.

In this paper we read, by means of a symptomal analysis, a selective primary literature written by engineers of the 19th century while taking into account the histories of feedback and control engineering. As we see it, historians of feedback have not sufficiently cut ties with institutionalized white-collar engineering cultures. Noticeably, Otto Mayr started from the self regulation of the steam engine by Watt’s governor in order to argue that it was part and parcel of a self regulated liberal society, operating under the auspices of the institution of the market, which dynamically adjusts demand and supply. In turn by attempting a historically grounded philosophical consideration, we try to show the limits of the feedback schema as supposedly providing both for market regulation and for technical regulation, by viewing it from the perspective of steam engine explosions.

According to our reading, Mayr has been right in drawing corresponding lines of the early conception of technical self-regulation (the first period of mechanical control) in terms of balance and equilibrium that corresponded to the liberal economic theories of supply and demand of the same period. These theories, however, of technical self-regulation and of economical self-regulation, remained incompatible with occurrences of steam engine explosions -over-pressure (boiler) and over-speed (flywheel) explosions- and economic crises in historical capitalism respectively. Engineers were ultimately unable to provide with a satisfactory account of the causes and solutions for the problem at hand. As we see it this was due to their standing at an intersection with the social.

Finally, another parallel line is drawn in this paper between the rhetoric of automation and liberalism. Feedback mechanisms continue to stand out as the *par excellence* techniques of intelligent control. An anthropomorphic perception of feedback mechanisms as minds of the engines stands not only for a contemporary deterministic view of technology by and large, but it is also closely related to a black-box ideology which has been underlying the dominant view of technology. Such an allegory functions in a double way manner defining at the same time both concepts of human and machine: it transfuses human properties to the machine (thus constituting the android its uttermost extension) while taking for granted such properties as inherent to a human individual, absolute proprietor of himself and of a free will.

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SCANNING ENGINEERING LIABILITIES FROM THE PERSPECTIVE OF AGGRIEVED PARTIES

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Abstract — Chinese economy is now at the rapid development stage, and especially the construction of infrastructure changes quickly. It is observed that the current China is a really large engineering country. However,while the modern engineering facilitates the living of most people, it also damages the interests of some people. The problems that attention should be paid to by the engineering ethnics are how to minimize the harmful effects of engineering activities and how to define the damages caused by engineering activities and the liabilities of concerned departments (e.g. planning party, design party, construction party and operation party, etc). Especially in China, it is very difficult to define the liabilities for the damages caused by engineering. This paper divides the harmful effects caused by engineering activities on interests into five types to be discussed, namely sustainable and temporary effects, conspicuous and inconspicuous effects, direct and indirect effects, avoidable and unavoidable effects, and recoverable and unrecoverable effects, so as to expect the engineering circle to pay attention to the liabilities in other aspects and to provide an empirical analysis basisi for defining the liabilities for the damages caused by engineering.

Index terms: Engineering, Liabilities , Ethnics

Now in China, the analyses on engineering liabilities, with interest relation as the logical starting point, mainly concentrate on the angle of engineering income which is greatly demonstrated in all engineering activities, plays a good role in understanding the positive significance of engineering benefiting the society, and well reflects the occupational responsibilities of engineering technicians serving the society. Moreover, the analyses only focus on macro level and decision-making design level, but study on material damages to some people at the engineering practice level is very insufficient. Although the demonstration of macroscopic profit level is necessary and general-purpose, it is far from solving the problems arising from contemporary engineering. As it is possible that every engineering activity may cause negative effects, engineering parties should bear the liabilities for the harmful consequences therefrom, but study on the angle of the liabilities is always ignored. The negative effects of engineering not only deviate from the value goal of engineering benefiting the society, the goal of society justice and other social and ethical values but also lay hidden troubles of social interest conflicts. The analysis on engineering liabilities from the angle of harmful effects caused by engineering and the anatomy of the logical relationship between engineering damages consequences and engineering activities are to avoid harmful effects caused by engineering more effectively, especially to reduce actual damages on the action level of engineering activities. At the same time, the analysis from this angle is helpful to understanding the comprehensive engineering liabilities.

We think that the damages of engineering to the interests of some people are different for the differences in modes and intensities of damages, magnitudes of engineering liabilities, modes to bear the liabilities and subjects to bear the liabilities and some damages are extremely invisibile and complex, which makes it very difficult to distinguish the liabilities. This paper divides the modes of the effects caused by engineering into different types so as to make better understanding of the relation between all parties involved in engineering and the damages caused by engineering and look for the subjects to bear the liabilities and the modes of conduct to bear the liabilities.

1. Sustainable effects and temporary effects.

We say that engineering is a kind of making activities in a specific natural environment and social environment, and thus it certainly causes positive effects or negative effects to the environment. The goal of engineering is to have sustainable positive effects on the society. For example the construction of a dam, we wish it to play sustainable active roles in irrigation, flood control and power generation. However, any engineering makes the society pay a cost, at least an economic cost, and the construction of a dam also needs to pay some social costs of which the main part is resettlement. Some effects are long-term, and some are short-term. Engineering should be liable to eliminate long-term effects and mitigate short-term effects. Taking resettlement as an example, the resettlement caused by engineering should be properly arranged, i.e. should make the resettled people adapt to the new living environment and repossess viability rather than the living on resettlement allowance. Therefore, what the society now appeals for is not to give the resettled people “fish” or “methods of fishing” but to give the resettled people “water” for them to live on, e.g. ecologic restoration that is to reconstruct an active ecologic system. Although sch problems have been thought much of in major engineering works, the bodied-forth liability concept has not been generally accepted by the engineering circle and the restoration of subsistence ecology is ignored. As a result, the following problems appear: a railway that runs through a natural village permanently separates people in the village who are originally in close connection in production and living; an elevated highway passes by a dwelling building, making the residents close to the highway have no peaceful days from then on. Specifically, Zhujiata Village, Xiaoshan District, Zhejiang is divided into two parts by Zhe-Gan Railway; newly constructed small storied buildings of many villagers are only 5-6m away from the elevated railway and the bed rooms are at an equivalent height with the railway, so the villagers feel that the trains run on their roves. On the railway without any isolation and prevention measures for the reduction of cost, trains run day and night and the vibration, noise, light at night and dust severely impact the living as well as physical and mental health of the residents. Furthermore, stones often fall from the rail bed of the railway passing through the courtyard, which directly threaten the safety of children and villagers walking in the courtyard.

The main liabilities for this kind of problems rest with the site survey and route selection design of the engineering. In engineering survey, natural factors and geologic factors are considered more and the feasibility in technical implementation is regarded as the most important thing, whereas the interests of damaged parties and the living quality of some people are considered a little. It is natural for us to question their understanding of the goal of engineering. The real goal of engineering is to benefit the society, so the liabilities for avoidance of damages should be considered as the equivalently important ones for benefiting the society. The survey engineers should put forward the interests of some people as an issue and calculate it into the cost according to the high level of social and economic development. The engineering design party is the one who puts forward the engineering proposal directly and is the one who has the coequal liabilities. As long as the surveyor has put forward this issue, the design party should be responsible to put forward the proposal for avoidance or elimination of relevant effects. It is a conscientious design proposal to make a detour for avoidance of effects and it is also a conscientious remediation method to keep far away from any housing according to the engineering standard and construct isolation baffles to separate pollution sources like noise and dust,etc. and prevent stones from failing from the rail bed. The renovation of Zhe-Gan Railway is made in the areas where there is a large population density and the transporation for production and living of people along the line are cut off. For this reason, the renovation includes the new construction of 1,439 culverts and 109 bridges, including 12 super major bridges, 86 major and medium bridges and 11 small bridges. Averagely, every 650m is provided with a crossing bridge or culvert to restore the transportation of affected people[1] and this is also a kind of remediation. Of course, the proposal put forward by the surveyor and the design party will be influenced and even decided by the investor or decision-maker. Therefore, we should not only strive for responsibilities but also establish a system of responsibilities to provide engineering technicians the system guarantee to stick to professional ethics and the work space to perform their responsibilities; however, they may not give up their responisibilities for the pressure from the investor or decision-maker. In fact, every responsible behavior faces pressures.

Figure 1 viaduct through the villages

Engineering construction is short-term as compared with operation, so short-term effects are generally caused by construction. The conscientious attitude to short-term effects is to minimize the effects. For example, a partition wall is constructed to avoid the danger to people for entering into the construction site, a temporary access road is constructed to avoid the traffic jam for the occupation of the road, the materials utilized in construction are covered or watered according to the rules to avoid the occurrence of sand and dust emission, and the construction operation with high noise is made within the specified period to avoid disturbing the residents. Some short-term effects can become long-term effects. For example, sewage containing sand would block the urban drainage system and even the sewage containing cement would form large cement blocks in underground drainage channels to block out the sewage system and result in long-term unsmooth drainage and even hidden troubles for urban flood discharge. This type of liabilities rest with the construction party, so the construction party should have the full understanding of and confidence in the nature and characteristics of own work and the materials used. There are national standards and requirements for construction, the responsibilities of the construction party are to make operation according to rules, have the full understanding of the inconvenience brought to people, and accept the opinions of the people and improve own operation at any moment.

Figure 2 undercrossing make up for the breaking former road

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[1] The 3rd version of Environmental Impact Report on Speed-Raising renovation Project by Electrification of Zhe-Gan Railway worked out by Beijing Aoxisi Environmental Protection Technology Co., Ltd. and China Railway Eryuan Engineering Group Co., Ltd.

2. Conspicuous effects and inconspicuous effects.

In this group of effects caused by engineering, it is very easy to judge conspicuous effects, so we pay our attention to inconspicuous effects. Inconspicuous effects refer to the changes caused by engineering in environment. This kind of effects would not doom to result in damages immediately, but it might result in a catastrophe when all kinds of factors occur at the same time. For example, in a university, when finding an old riverbed at the location where the man-made lake was to be constructed, the construction party got sand and stones locally to construct the lake. The construction process was relatively long and several heavy rains formed a rain-pool. However, the construction party did not make the lake according to rules; instead, they carried out excavation on the sly. Since the lake bottom was uneven and the lake depth differed greatly and there were hard construction wastes backfilled by the construction party into the lake, the lake had taken away the lives of several people and the lake became a potential safety hazard. In this case, the party directly liable should be the construction party, but the supervision party and acceptance party should be also liable for oversight.

Such instances that the existence of hidden troubles is tolerated for economic benefits can be seen in international community. For example, the collapse of New York World Trade Center in 911 Event took away the lives of more than 2,000 people. Of course, we need to condemn the terrorists by all means. However, the investigation after the Event made us know that the decision-makers and designers found in their early design that the proposal designed according to the building code of New York City in 1945 could not provide sufficient space to be leased out to maintain the economic returns of the building. Therefore, they changed their design proposal to give up the construction of earthwork or concrete structure around the stair well. In consequence, fire fighters could not enter into high stories and people above the fire point could not flee from the fire when the event occurred. This changed design proposal was permitted by the government of New York at that time[2]. In this case, the city government should be of the parties directly liable.

Figure 3 potential safety hazard in sharp turn

This type of inconspicuous effects will emerge after a period of time. For example, the ecologic effects of the sediment trapping design of Sanmenxia Dam was thoroughly ignored under the specific political and economic background, in which the ecologic environment consciousness of the whole society was very weak for the scientific and technical level at that time.

Figure 4 the undercrossing without drainage is unsafe when it rains

3. Direct effects and indirect effects.

It is difficult to determine the relation between the result and acting party of the indirect effects, so the emphasis of the understanding of this group of effects is indirect effects. In a sense, the analysis of the relation between the aggrieved parties and the engineering parties needs technical knowledge and information which are difficult for common people to master or know, so indirect effects depend on the professional responsibiliy consciousness of engineering technicians and the guarantee of the engineering management system much more. Moreover, indirect effects also involve various possible reasons for damages, different positions and functions of different factors, and the liabilities that should be borne by engineering parties, etc. For example, the 35km long sector of Tai-Zhong-Yin (Taiyuan-Zhongwei-Yinchuan) Railway in Fenyang, Shanxi passes through 4 towns and townships and 35 administrative villages. Yudaohe Town and Lijiazhuang Township are arid all the year round and the water used for drinking of human beings and domestic animals and for irrigation of farmland mainly depends on 4 spring heads, namely Xiangyangxia Spring, Shanglinshe Spring, Shentou Spring and Songjiazhuang Spring. After the construction of Luliang Mountain Tunnel in Fenyang was started from Feb. 2006, these 4 spring heads had become dry and offset time after time. Especially, the flow from Xiangyangxia Spring and Shanglingshe Spring decreased ceaselessly and became thoroughly dry in Nov. 2006. Shentou Spring in Yudaohe Town also decreased from the average long-term flow of 0.30m3/h to 0.15m3/h. The flow from other small springs also decreased sharply. Therefore, the drinking water needed by 11,171 people and 749 domestic animals of 19 villager teams in Yudaohe Town and Lijiazhuang Township faced a severe threat and neighboring ecologic environment was obviously deteriorated. The local governments and water resources developments deemed that the water break was the result of the extrusion against the rock and soil during the excavation of the tunnel. In fact, Tai-Zhong Railway was constructed in a hurry, the time limit for the project was very short, and the cases that the design, construction and modification were

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[2] The 4th version of *Engineering Ethics Concepts & Cases* written by Charles E Harris et al, translated by Cong Hangqing et al, and published by the Beijing Institute of Technology Press in 2006.

made at the same time took place frequently. For the shortage of running cost at the early survey, simple engineering survey and insufficient survey demonstration resulted in that the deliberateness and scientificalness of the survey could not meet the requirements. The design party knew the complexity of local geologic and hydrographic conditions and the weakness of the groundwater flow system, but it only marked on the design drawings to call the attention of the construction party, without any more technical requirements put forward for the construction party or any technical precautions taken in the design.

In Jul. 2007, the Leading and Coordination Group of Luliang City formed the findings into the report of *Letter on the Issue Concerning Solving Spring Water Break Caused by Tunnel Construction on Tai-Zhong-Yin Railway as Soon as Possible*, submitted it to the Development and Reform Commission and Department of Water Resources of Shanxi Province, and to Tai-Zhong-Yin Railway Co., Ltd. However, the leader of the project disagreed with this conclusion and he opined that the project had passed the environmental impact evaluation and it couldn't be determined whether the water break was caused by construction. Since the problem concerning drinking water couldn't be solved for a long time, the masses had much complaints, and even appealed to higher authorities for help and blocked the construction vehicles. In order to ensure the interests of the masses and maintain the stability of the society, the local government and the construction party reached a common understanding to lay the investigation of liabilities aside and solve the drinking water problem temporarily through groundwater abstraction by Water Resources Bureau of Fenyang City with the fund provided by China Railway 12th Bureau. [3]

In this case, the effect of the construction on the spring water break needs to be professionally and technically determined, and it is unfeasible only to determine it by experience. It involves how the initial environmental impact evaluation is made at the demonstration stage and who can see relevant information and data. Moreover, it is possible that a problem is caused by various reasons. In the second half year of 2007, the rain water in the area was relatively abundant that seldom appear in the area. Thanks to the abudant water, the drinking water problem was mitigated to a certain extent. So, it is obvious that construction is not the only reason. Furthermore, the engineering mode of making design, construction and modification at the same time is really unscientific and irrational. In this case, the design party, survey party and construction party would bear liabilities in stead of the decision-making party. At the same time, the pressure of the supervision party would be heavier. All these are adverse not only to the division of the liabilities but also to the independent bearing of the liabilities. If the party liable could be found out through clear findings, the party liable would be a group with very complex relations in liabilities.

4. Avoidable effects and unavoidable effects.

The avoidable effects and unavoidable effects are relative and they can be relative not only to the technical level and cognitive ability at that time but also to the construction party's sense of responsibility. For example, the damages caused by jerry-built projects are the typical results of neglecting the responsibilities for engineering or seeking profits, including several kinds of damages caused by engineering we analyzed before. In a sense, the negative effects of these kinds of damages can be avoided as long as the consciousness of responsibility is intensified and the system is normalized. However, it is unavoidable for engineering to have effects on a small quantity of groups. For example, for lots of projects, especially large projects, resettlement is necessary; civil capital construction always needs to be made in a specific space to affect the balance of the nature more or less; the transport and noise pollution during construction always bring inconvenience for the people around the scope of the construction. All kinds of measures should be considered during decision-making, design and construction to minimize these kinds of effects. There is another kind of effects that cannot be avoided on the scientific and technical level and the social and economic level at present, such as the effects of engineering on ecology, the farmland occupation of engineering, and the effects of nuclear engineering and chemical engineering on the environment and so on. This kind of effects can be expected to become avoidable along with technical advancement, for example, ecological rehabilitation after engineering and mellow soil backfill after mining to return the farmland to peasants to reduce the number of peasants leaving home or farmland. Even for unavoidable effects, engineering parties should make compensation. Especially for effects involving the right of basic existence, engineering parties must make compensation and the benfits of engineering cannot be exchanged for with giving up the legal rights of a small quantity of people. It should become our common understanding that all citizens in the whole society are entitled to share the achievements of social progress.

Figure 5 Zhe-Gan railway directly through the villages withou sound insulation

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[3] *Collective Public Administration Cases (Volume 1)* edited by School of Public Administration in Southwest Jiaotong University, Sep. 2007

Figure 6　wires and puddles on village in dense population

5. Recoverable effects and unrecoverable effects.

The unrecoverable effects of engineering are mainly embodied that they have changed the natural state and broken the natural balance. However, along with the passing of time, these unbalances would be rebalanced. Although some projects need a long time to realize the new balance and even expand the disaster phases of the damage ceaselessly, the peaceful balance period would come forth finally. For example, the disaster at Sanmenxia expands in a relative period. Therefore, for the infinite time, all effects are relatively recoverable and unrecoverable effect only refers to the effect in the disaster phases. We still take Sanmenxia for example: after the sediment trapping and water accumulation proposal was brought into effect for more than one year, 1.53 billion tons of mud and sand were rapidly silted in the reservoir and 94% of incoming mud and sand was silted in the reservoir, making elevation of the riverbed at Tongguan elevated 4.31m at a draught and making Weihe River form a entrance bar. The superposition of the backwater and the flood in Weihe River made 250,000 Mu land along the river submerged and 5,000 people besieged by water. [4]Although the renovation project aiming at rehabilitation was commenced in 1965, two tunnels were opened at the left bank and 4 pieces of steel pipes were used for sediment outflow, the mud and sand brought in the flood season in 1966 was not stopped, the riverbed of Weihe River continued to rise 0.7m, 2 billion tons of mud and sand continued to be silted, and Weihe River extended upwards. Once being broken, it is very difficult to rehabilitate the natural balance. The main liabilities of this kind of problems rest with decision-making and design parties. The decision-making party violated the natural law and insisted on making the Huanghe River clear, and the designer party catered to such decision-making and craved for greatness and success to put forward such a high dam sediment trapping design. For this kind of problems, the most effective method is to put an end to them at the decision-making and design stages. Therefore, scientific development concept and the scientific spirit seeking truth from facts should be always the attitude of decision-makers and designers to professional responsibilities. Sometimes, people make a fetish of efficiency and even consider it as the foremost. It is obvious that higher such efficiency is and more severe the disaster brought by such efficiency for the society is. Efficiency only indicates the relation between the acting and result and it doesn’t reflect the justifiability of the acting or the values of the social entities.

According to the analysis of above several kinds of effects caused by engineering, we know that lots of damage effects can be avoided, mitigated or compensated as long as the parties involved in engineering fulfill their obligations earnestly. The method in line with ethical spirits is to assure the interests of aggrieved people rather than give up the benefits of some people when engineering activities benefit the society.

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[4] P122 of *Talk about the Merits and Demerits to Dam in History* written by Pan Jiazheng and published by Tsinghua University and Jinan University Press in May 2000

On the Ethics of Engineer

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As a kind of career of participating in engineering activity, does engineers exist problem of normal or ethics? Or can we say, does the Ethics of Engineer exist? Two contrary points of view exist: one of them is negative. It argues that engineering technology is value-free, engineer has no moral responsibility for his technological activity. Among the epistemology about science and scientific knowledge, philosophers such as Hume, Kant, Wittgenstein, Carnap, etc, all think that scientific knowledge or science have nothing to do with normal, scientific activity does with no personal value, scientific activity is value free. In the field of engineering technology and engineering technology knowledge, some scholars such as Mesthene, Sax, and Dessauer, etc, put forward the thought of Value-free of engineering technology. They think that the persons who participating in engineering technological activity should not responsible for such activities; the other kind of views of point argues positively that engineering process is a kind of technology-ethics practical process, it including the value evaluation for good or bad. Here we also investigate the views of some scholars such as Mario Bunge, explores the nature of technology-ethics practice of engineering activity or technological activity. And then, this paper addresses in detail the ethical fact in engineering activity from 5 aspects, also analyzes the behaving forms of engineer ethics. Each of the 5 aspects is: the engineering practice activity of engineer, the interpersonal relationship between engineers, engineering study, the attitude of engineering activity to the natural environment, the attitude of engineering activity to the public benefit. Through the exploration of the 5 aspects, the paper analyzes the nature of the ethical responsibility of engineers. After that, we explore the origin of the ethical behavior of engineers. Based on the thought of Amier Turgeon, and Nilson, we explore the several behaving style and character of the ethical behavior of engineers. We argue that the ethical tropism of engineers in engineering activity is very complex and changefully, it should not category easily into several modes of ethical behavior, but should analyze the key factors that impact the ethical decision-making of engineers. Therefore, we explore the several mechanism that impact the ethical behavior of engineers such as individual value conception, social cultural, and natural environment. We think that such several factors play an important role in the influence on the ethical decision-making of engineers. In summarization, this paper explores the following problems: (1) does ethics of engineers exist? (2) what is the behavior form of the ethics of engineers? (3) the analysis of the origin of the ethics of engineers. (4) the key factors that impact the ethical decision-making of engineers.

Key words: engineers; moral; ethics.

Resources for an experimental course in ethics

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INTRODUCTION

Technology and ethics was the topic of a recent experimental distance taught course using synchronous and asynchronous e-media. This pilot was offered to a restricted number of ITliterate practitioners without formal background in ethics.

Offering the course across disparate time zones meant synchronized sessions were limited thus a question posed in planning was "What resources should the students study between the synchronous sessions to ensure a lively and economical debate?".

In this account we describe some of the resources that were deployed and what they offered.

STYLE

The style of the course was prompted by work on dialogue as a medium for learning. As Göranzon and Florin (1991) wrote, "Dialogue is one of the keystones in the development of . . . ethical thinking".
In another article with Sällström they explained that dialogue clarifies issues and they also indicated it is worthwhile attempting "to elaborate on the phenomenon of dialogue".

They turned to the theatre to illustrate dialogue as a medium of transformation and suggest
"Dialogue occurs where roles meet; it sets them in motion, leading to unexpected shifts"
Göranzon et al. (1991)

Engdahl (1991) explores different interpretations of this shift. In the context of ethics, this can result in the development of knowledge about ethical arguments or discoveries about how situations can evolve in unanticipated directions. Pfister (1998) also hints at the utility of dialogue in exploring challenging ethical issues when he refers to "[d]ialogue's tendency to centre on the questionable and the insoluble".

VIDEO MATERIAL

An early session aimed to open up a dialogue amongst participants.
To provide common ground for discussion a video was made available via a video sharing site.
The video posed questions about the visual intrusiveness and the radiation hazards from radio masts set at regular intervals for communication with trains. The video was produced in-house thus skirted rights issues and required minimal production or viewing effort since it lasted only thirty seconds, nevertheless, since views on visual intrusion and opinions derived from fears about radiation from radio masts are commonly and strongly held, the video resource triggered an animated dialogue.

SOCRATES

An obvious and practical source of material readily available on-line are the Socratic dialogues. There are copyright issues because of the need for translations. Copyright-free translations are older and not as lively as recent versions. Additionally technical occupations only receive limited attention in the dialogues. So some interpretation is required to show the relevance of Socratic dialogues specifically to engineering and technology. Consequently only a few brief extracts from Gorgias were explored.

However, the Socratic dialogues do clearly illustrate styles of presentation. Firstly they distinguish different forms. The voice of a single narrator presents Protagoras and Meno has the appearance of a play script though Meno continually agrees with Socrates. In Gorgias, Socrates with his bullying ways propels the argument forward and the dialogic form allows others to intervene. Socrates then deals with any objections. In this way the dialogue refines a philosophical view, though ultimately Gorgias slips into a Socratic monologue.

Secondly the dialogues illustrate the use of rhetoric in ethical debate. In Gorgias, Socrates challenges the importance given to rhetoric but ironically exploits rhetorical skills. Cunningly his analogies shift the argument to domains where agreement over questions of value are widely accepted. Stories and quotations in the dialogues similarly deflect and grip the reader's attention and bring in additional authorities in support.

THEATRICAL TEXTS

In a volume dedicated to philosophical dialogue, Nussbaum's (1998) contribution is noteworthy for, amongst other things, the mixture of styles of presentation. It is in the form of fragments of a lecture, which illustrate the abstract didactic rationalising of philosophical dialogue, interspersed with conversations between the lecturer and the spectres of her dying mother and father. In a single work therefore philosophical writing appears alongside dramatic fantasies, personalized and rich in ethical issues.

Pfister (1998) contrasts philosophical dialogue, which characteristically portrays an exchange of views and arguments, with dramatic utterances where something is being done by the person uttering and he also warns that enacted philosophical dialogue can be "rather poor drama". Broadly, philosophical dialogue pays attention to the argument rather than the more engrossing transformations of relationships between the characters.

Characters are vital components of theatrical productions which have proved drama is a powerful way of presenting situations that encourage significant ethical debate. Epic dramas can make their point forcefully but often refer to largescale abstractions like nations. Such dramas are allegorical and as with philosophical dialogue demand effort in drawing parallels with everyday activities. However and importantly some dramas deal with relationships on a scale that can be related easily to everyday experience.

Theatre with commercial pressure on space and cast size must find popular ways of projecting issues through the voices of just a few actors. In particular, theatre must make performances both relevant and personalised and in contrast to philosophical dialogue, theatrical drama, which is free of demands to present a rational dialogue, offers a range of expression that accommodates conflict and difference.

RELATIONSHIPS

The affiliation between the BBC and the Open University allowed us to commission four radio plays and to retain replaying rights for the University's students. Two sessions of the experimental course therefore required students to download and listen to two plays. These two plays are linked by a fictitious incident in which a technician working abroad for a communications company is reported missing. The first play (Hims, 2006) is situated in the technician's home with his desperate partner, Carol. In spite of her collection of communication devices, Carol does not know what is happening. Ill-informed and lacking authority or resources, she can only wait and instinctively develop her network of relationships within the constraints set by communications technology.

In ethical terms relationships are valued. That valuation is asymmetric, and in the course of the play the characters make efforts to strengthen, weaken and exploit those relationships. So here ethics is coupled with building relationships that give the authority to act and that offer reliable channels of communication, but with different interests at stake even advancing those relationships can generate conflict.

LOYALTY

The second play (Walker, 2006) illustrates the fierce loyalty that people can show towards an institution like a company and how that loyalty strongly influences their judgements.

The play also illustrates ethical statements and arguments cropping up in everyday conversations. There is, of course, a crisis in the company but people's behaviour is not dissimilar to their behaviour in other circumstances. For instance, the characters reveal the things they value including having ideas, having skill, loyalty to the company, not interfering, getting on with things and even ICT itself.

There are a number of incidents which throw up ethical questions notably when the security chief explains it is "easier to open a human being than an encrypted laptop". Amongst senior management, the outcome of concern is that the "laptop is uncompromised" Their logic suggests the company must conceal its secrets, to protect a contract, the jobs it brings and hence the benefit to the local community.

Their justification for any damaging actions exploits the dubious analogy that suggests you cannot "fight a war without taking . . . casualties?".

RIGHTS

For the last two sessions students were mailed individual copies of the relatively cheap paperback script for the play Landscape with weapon (Penhall, 2007).

In the play, a dentist, sees a business opportunity in providing cosmetic surgery to those in the dentist's chair. He justifies his moneymaking by saying it benefits his family. His brother, a weapon designer, is initially unperturbed by involvement in the design of swarming military drones. His justifications are the common and often respected defences for those working on military projects.

In spite of being disturbed by the defence project, the dentist feels his brother should negotiate a good return. The company is keen to exploit the work but the weapons engineer wants to enter the wider world of politics using the "rights" to his ideas as an instrument. He fails to recognise his dependence on others. It is a weakness exploited by company personnel who float threats to kill the project and thus devalue the design which had become, for the designer, an integral and precious part of his identity.

In one speech, the designer reveals the ethical situation of the engineer. Firstly the engineer's prime task is "to make a machine or technology as effective as possible", secondly there is the designer's imperative to discover something which is gratifying to the designer and potentially to the engineered object's audience and thirdly the technology may have effects that conflict with a "personal morality".

CONCLUSION

Dialogue provides a foil for exploring ethical issues. This points to a need for engagement in dialogue and the study of the forms and techniques of dialogue. In a recent experimental course, plays provided the primary materials for exploring dialogue and means were found to deliver at a distance suitable illustrations, texts and performances.

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Physics Limitations and the Philosophy of Technology

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Until the first half of the nineteenth century the scientific environment became more distinguishable, when

1- The science is able to explain the nature in a more convincing way than that of metaphysics, or theological theories.
2- The large activities and accumulations of science.
3- The increasing of popularity of science in favor of theological or metaphysics studies.

That advance of science lead the philosopher Auguste Compte to his law of three stages, and that might mark the formal establishment of philosophy of science.

In last century the pure physics was the most branches of physics and science that draw the history of physics development, when the Relativity and Quantum physics became the revolutionary great achievements. The excitant agreement between the theoretical predictions and explanations with the experimental investigations were the great support for that branch of knowledge. Those great accumulations of achievements during the first three decades of the last century were behind Gaston Bachelard's declaration of his new scientific spirit, or a new a philosophy of science.

The accumulation of any thoughtful achievements looks as the leader to a new system of idea (philosophy), this process may be in some how similar to Khon's revolution process.

The great achievements of pure physics made it very popular and gained a huge number of research grants during the last century. This honeymoon of theoretical physics did not continue. It reached its end in the second half of the twentieth century, when a declination started to appear. The main problems that might be behind the declination of pure theoretical physics are:

1- Most of the theoretical predictions of physics for the second half of the twentieth century in microphysics (like String theory) and cosmology (like Black holes theories) facing large experimental investigation obstructions. The nature of the theoretical works makes them grow and accumulate rapidly in relative to the excremental investigations technology. For new investigations, more advanced and sophisticated technology is needed or it well needs a technology beyond the present science bases (like space travels). So there are sort of inabilities of experimental investigation to probing the boundaries of our realm. These boundaries are the limits of the microscopic and cosmological nature. That is meant we are facing an end of our usual probing investigation. In theoretical physics now a huge number of theoretical works without investigations. Millions of research articles around the world are looking for evidence. This case is similar to the case of the inability of the theology in proving its theories, and then a huge accumulation of theological theories are without evidences.

2- Since the nineteenth century or before, and owing to the huge accumulation of science achievements, a large interest in utilizing these achievements in industrial applications has been started with accelerated growth. This case attracts the new generations of students to choose the technology or applied sciences for their future rather than pure physics. This case in some how is similar to the case of the starting of domination of science studies over the theology; and then the academic approach turned to science more than the metaphysics or theological studies, during the seventeenth to nineteenth centuries.

These problems may put the pure physics in a situation similar to that of metaphysics case during the first half of the nineteenth century. The technology became more and more demandable, with a great growth. It is clear that there is a new human development!

- Is this new development in human achievements (technology) accumulated and may lead to a new type to philosophy?
- Is new wave of thinking philosophy, ideology, or just arranged thoughts?
- Does the new philosophy have the traditional features of philosophy?
- Is the new philosophy, the new step in addition to the three steps of August compt?

The intensive interest in this type of thinking has been started in the mid of the last century when the technology achievements appeared to be accumulated and with serious effect on human society as in the works of Martin Heidegger and John Dewey. This new type of thinking is adopted academically, and many philosophers are considered to be as technology philosophers. Most of the works of those philosophers are interested in the social effects of technology. Technology, is more complicated than the consideration of the social feature as normally considered by the philosophers.

However, these problems of pure physics may lead to make the domination for Practical physics and Engineering physics in the third millennium. But the real domination will be for the Engineering physics or technology rather than Practical physics. That is owing to the demand on technology.

Technology depends on engineering, engineering physics (or science), trade, politics, sociology,…So a new philosophy will be started effectively in the third millennium owing to the new application or dealing with science that is the Philosophy of Technology.

Technology started effecting human society since the nineteenth century. The wars disasters were based on the technology developments. Technology development may have the natural growth exponential curve, and a great and fast development accumulation of technology may be noted.

Technology Games

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DEMOLISHING DISTINCTIONS

Haraway's Cyborg Manifesto (1991) removes distinctions and renders uses of language ineffectual by recognising cyborgs as "hybrid entities that are neither wholly technological nor completely organic". The cyborg therefore disrupts "persistent dualisms" and consequently refashions our thinking (Balsamo, 1995, p.11). This tactic can also be exploited to question the distinction between language and technology.

In Wittgenstein's terms, the Cyborg Manifesto questions the implicit rules of certain language games. In his Philosophical Investigations Wittgenstein likens uses of language to games. His initial illustration includes the words spoken in constructing a building (Wittgenstein, 1992, x2 –10) and later he offers examples of language games that include measurements, drawings, tables and diagrams. They suggest the boundaries of language are hazy and might be extended to include other forms of human expression.

ARTEFACTS

Words, like vulgar pots, are crafted bodily from physical materials, but language can also be expressed by speech synthesisers, radios, printers or scoreboards. Words, like any other
artefact are manufactured human expressions created with or without the aid of tools.

Like any artefact, or expression, fragments of language create impressions. They affect people, can generate electrical signals or fill pages in a book. Thus words, like tools and weapons, are productive. Aggression, carelessness and caring are expressed with words but also with cars, knives, litter and birthday cakes, for instance.

A breach of the distinction between words and other artifacts suggests that language – Brailled, signed, written and spoken language—is a collection of technologies thus, with the loss of contradistinctions, language games become subsumed into the spectrum of technology games.

CHILDREN'S GAMES

One of Pieter Bruegel the elder's pictures shows children playing games in the street. Artefacts accompany many players and are an integral part of their games.
"Ranging from toddlers to ungainly youths, they roll hoops, walk on stilts, spin tops, ride hobbyhorses, engage in mock tournaments, play leapfrog, shout into empty barrels . . . dangle streamers . . . [while] a boy amuses himself by balancing a broom on one finger." (Gibson, 1977, p.85)

Some games engage a group, some just two players, others are conducted alone. In some games, everyone has a similar role, in others there are distinguished roles. Some players are skilled; others are clumsy. Some children drift from game to game. Some games are competitive and others cooperative; some are make-believe. The point of some games seems to be to disrupt other games. Each game is distinguishable by the number of players, the children's behaviour, the artifacts used and the ways in which they are used.

A classic book on children's games describes the rules for such games (Opie and Opie, 1969), but these rules can only be an account of what the children have been observed to do. And where the apparent goal of a game is given, it is similarly an observation about the trend of play. It is to be expected that children simply know how to play the games and learn by watching and imitating others.

EXPRESSION AND IMPRESSION

Playing games is a mode of expression. Within the game players or teams express themselves in individual moves but the whole game too is an expression that might be seen as a move in a broader game. Thus boundaries between games or expressions are artefacts of particular analyses.

Expressions can be transient, like speech, or enduring, like writing. Technology games utilise expressions since moves and the games themselves create lingering impressions on the players, spectators or materials. Participants remember and mimic moves they have seen, and when in a material form impressions, the by-products of games, can be a series of enduring artefacts.

Expressions are bounded by the availability of materials, time, space, energy, skills and tools. Such constraints can limit linguistic expression but less severely than a game that, for example, aims to build a ship. Constraints are liable distort expression and occasionally render a game unplayable or unrecognisable. To overcome constraints some technology games, therefore, adopt readily available objects, including the impressions left by other games, as components of their moves.

INNOVATION

Metaphor, a source of novelty in language, is a benign, evocative, purposeful, grammatical blunder. Donald Davidson (1978) regarded metaphors as common words tangled in language games in which "a sentence used metaphorically" is "usually false" . Metaphor parades its falsehood and encourages us to seek what was, before the use of the metaphor, an inexpressible impression. Some metaphors fail but others catch on and, consequently, as Wittgenstein (1992, x23) remarked, "new kinds of language games come into existence".

Translated to technology, metaphor is an innovation the deliberate, apparently inappropriate deployment of an artefact that may allow us to generate new impressions and create novel games. An innovation may prove useless, but may be imitated to become commonplace. Innovation thus can change the ecology in which technology games thrive.

EFFECT

In a classic text on games Caillois (2001, p.5) sees play as "an occasion of pure waste" and separates play from "real life"; yet Glasberg et al. (1998) point out, gender, race, class and political identities influences "how we interpret the rules of the games, and . . . facilitates resistance and reinterpretation of our social identities . . . even when we think we are simply having fun and playing" . Thus while Caillois sees games as creating “no wealth or goods”, Glasberg sees them as productive in altering identites as might expected with activities that bring players and artefacts together in close proximity.

Thus play can contribute to the construction of identities, rivalries, alliances that endure beyond episodes of play and hence reinforce or disturb a social order. Play may not bring riches but it can have effects on the players and spectators that change the way other games are played. Concerns over games show there is a widespread belief that games have effects beyond their boundaries (Chapman, 2008). Games therefore become linked by what might be considered their side effects to create, to paraphrase Lyotard (1984, p.17), flexible networks of technology games.

ENGINEERING TASK

Rules are constructions summarising past behaviour or expectations of future behaviour. Rules cannot anticipate the circumstances of players so games offer room for manoeuvre nevertheless clumsiness, deceit, improvisation, contradiction or misinterpretation can lead to explicit rules being transgressed. Thus new games emerge by chance. But engineering is about the deliberate creation of novel games and in their professional role engineers are not the players. Engineers steer new or modified games into existence, where existence implies having material components, established rules for making moves and players willing to play.

The creation of the equipment for a game is wasteful before players are willing to participate. Skill or equipment, however, are not required for discussions about a game.
Bruegel’s picture illustrates a simulacrum of a game can trigger a conversation. Engineers therefore create mythical accounts of a game being played, which exemplify the movement of mythical or transposed artefacts and players. If conversations about the mythical game catch on then elaboration of narratives answers questions about the realizability and acceptability of the novel game. Refinement continues until comprehensive stories emerge about how artefacts will be used in a novel game and about the rules of a technology game that will express the required artefacts.

Throughout this game of engineering development engineers deal in visions of games and artefacts and exploit storytelling technologies such as meetings, drawings, mathematics, prototypes, computer programs, films and models.

ENGINEERING GAMES

Caillois (2001) provides descriptive terms that can be applied to games — competition, chance, mimicry and thrill. Competitions set out criteria for success, for example utility. These criteria of success are characteristics of particular games. In some contexts engineering is an economic game; in others the criterion is effectiveness, sustainability, attractiveness or verity. Often it is an ill-defined combination of these things.

Engineering can also be portrayed as a game of chance that gambles on closing the gap between a vision and material fulfilment.

Mimicry is a primary tool of the engineer who deals in a variety of simulations, models and prototypes. It is hard to say which is the mimic—the idealised engineering vision or the constructions derived from the drawings, equations and specifications.

Caillois’ final descriptive term is akin to thrill. Thrill for the attempt, in the face of uncertainty and unruliness, to transform an ambition into material results which turns engineering into a roller-coaster of hope.

CONCLUSION

Technology games are parts of ways of life. The rules of technology games are the customary restrained practices people engage in, in consort with artefacts. Artefacts are not media shaping themselves more closely around human needs but are active participants in technology games which constitute nations, genders, professions and so on. Gradually, the technological ecology changes and consequently self-images change.

Engineering is itself a technology game that attempts to turn visions of other technology games into a material form. Engineers are thus cultural leaders who regulate self-images through innovations in artefacts and proposed rules for their use.

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Common sense in using simulations

Computer simulations as a topic for the philosophy of technology

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Keywords

Simulation, complexity, common sense, tools and media, terms of reflection, rationality.

1. SIMULATIONS, SCIENCE AND TECHNOLOGY

Simulations and dissimulations have been topics of philosophical thinking for thousands of years. From Ovid to Baudrillard, they have been addressed in various ways. In science, the usage of mechanical devices to illustrate and study natural phenomena has a long tradition, too, especially in astronomy. Simulations as we see them today are therefore basically nothing new. Only the way how and where simulations are created and run has changed since the computer was introduced. Several authors have recently studied how science is affected by this change. A common understanding seems to be that scientific research itself does not gain another quality by the usage of simulations. More likely, the change seems to affect the philosophy behind science [1],[2]. Even so, it remains unclear what is actually new. Several clams have been made about the epistemic, semantic, metaphysical or methodological impact of simulations on science, but at a closer look, they all seem to be rather weak [3]. Although computer simulations feel new, it is very hard to find any particular aspect in which they challenge the philosophy of science. In such a situation, we have to rethink our point of view. This paper therefore discusses the proposition that computer simulations should not be regarded as a topic for the philosophy of science, but for the philosophy of technology.

2. WORK BEYOND KNOWLEDGE

Computer simulations have become very popular in many fields of research where complex and dynamic processes are studied. Descriptions of the benefit in science from simulations usually highlight four different aspects [4]:

- visualisation of structures and processes,
- access to the object of research,
- enablement of experimental studies,
- insight into what happens.

Such descriptions make clear that simulations as tools in science have another quality than microscopes, calculators or measuring devices. The latter give access to information which leads directly to knowledge as the objective of science; in simulations, the relation to information is more obscure. A direct link from the simulation to the production of scientific knowledge does not exist. In fact, all the aspects mentioned above are no characteristics of the usage of simulations in science; they also apply to simulations in education and training, business economy and engineering. In education, for example, a simulation also visualizes facts, reproduces conditions of a real situation for the students and lets them gain insight, but the simulation does not lead to the production of knowledge: its informative content is quite clear from the beginning and the objective on using the simulation is making the student learn ho to act well with it. In similar ways, business simulations or product simulations help managers, designers and engineers to work. We can conclude from this that simulations should be discussed with respect to what and how people act and not to the information given in it.

3. THE UNIQUENESS OF SIMULATIONS

Like most simulations in science, climate simulations are combinations of huge numbers of single functions and procedures describing meteorological processes. Each of them requires its own variables and parameters. A common argument for the usage of these simulations is that they work on information gathered from the real word [4]. All there is to do, one might assume, is collect the information about climate from research stations and fill it into the given system. The effort to calibrate the system is often ignored. Variables and parameters set directly from the sources almost always lead to absurd results. In order to get a reasonable simulation, it is necessary to preselect and adapt the input data.

Simulations in training usually work in an interactive way. A variable flow of input information during the operation of a simulation is already part of its concept. Ruling out input that leads to absurd results is part of the intended pedagogical effect. In business economics and engineering, simulations also help to compare how different strategies, visions and ideas turn out when they are combined in a complex system. Most of the times, the grade of complexity of the system is so high that there is no way to rule out all input that leads to absurd results right from the beginning. The accomplishment of good system behaviour is therefore most of all the avoidance of bad input; there is no way to extract a general rational rule of how to handle the system from it. Under different circumstances, the same sequence of conclusions might lead to bad results, because of a different interaction of the single parameters.

In all cases, the act performed with the simulation is unique, depending on the people who worked on it and not transferable to other circumstances.

4. PROBLEMS OF THE TOOL METAPHOR

Technology organizes human work in functional patterns of means and objectives [5]. Tools are abstract concepts of such patterns. Because of this abstraction, it does not matter when and where and by whom tools are used. The functional pattern of the tools excludes all these questions and makes the tools generally applicable. In fact, tools can also be operated by a machine instead of a human actor. Simulations are technical artefacts that can be considered as tools because they are operated in a certain way and calculate certain results according to their program code. This understanding of simulations, however, does not address the pattern of action which is characteristic for their usage as it was described above. The abstraction from the user blocks the view on what the application of a simulation really means, because the way how he operates the simulation and what he gains from it are essential parts of the description of the simulation itself.

Several authors have extended the tool concept by looking at the space of potential objectives for which a certain artefact could serve as a means [6],[7]. When tools are discussed with respect to the space of potential usage, they are often called media to emphasize the difference of perspective. Although this can be helpful in many contexts, it does not seem to cover the peculiarities of a simulation either. In the media perspective, the human actor appears as the person who imagines the potential usages of a tool and makes a choice between some of them. After that choice, the actor is still excluded from the functional pattern. For simulations, such a distance to the actor does not exist.

5. SIMULATIONS AND REFLECTION

From a Hegelian perspective, technology can be interpreted as the way how an actor establishes a distance to his acts in order to control them [8]. Distance is a prerequisite for reflection and in this sense technology becomes a term of reflection [9]. For Hegel, reflection takes place when a difference between what was intended and what was found in the real world is detected and overcome. The result of the reflection is once again a distance between the actor and his action. The artefacts of technology represent the progress of reflection. When we invent or improve tools, we set ourselves into a new relation to our actions. Or, in other words [10]: the development of tools shows how we apply our common sense and learn from experience.

If a distance between the simulation and its user cannot be established, the conclusion must be that we cannot learn from a simulation like a tool. And indeed, the pattern of simulations describes a different kind of learning, because it already includes common sense. Simulations do not discriminate actor and functional procedure. They combine the identification and selection of means and objective with the application of these means and the interpretation of the results. If there is any distance to be established in the pattern of a simulation, it is a distance between the acting situation and the rest of the world. Reflection is inside the simulation, not about the simulation.

In this way, simulations are not designed for the organisational effect that tools have for our actions. Instead of reflection devices, they are more likely refection environments. Instead of providing experience to learn from, they provide effects of learning from experience. They must be considered on the same level as our common sense, our rationality itself.

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The philosophical landscape of spaceflight

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ABSTRACT

Spaceflight as a branch of engineering and technology has a unique connection to philosophy from its birth and throughout its ideological history. There is hardly an engineering branch where the philosophical argument is used as frequently as in spaceflight. Several concepts can be identified: The “utopia” created in space, the next step of evolution of mankind, the solution for problems of mankind and the pragmatic approach. The discrepancies between these rationales pose a dilemma for the future of spaceflight. This paper intends to give a brief overview over past and current tendencies of the philosophy of spaceflight, which is mainly “human” spaceflight.

KEYWORDS: spaceflight, utopia, evolution, astronautics

INTRODUCTION

Spaceflight is a quite new branch of engineering and is treated here as the sum of all human induced activities in space or related to them. “Space activists” are treated here as people involved in the realization, advocacy and representation of spaceflight.

THE BIRTH OF SPACEFLIGHT

The theoretical background for spaceflight was developed by a range of space pioneers. The most influential and largest work was produced by the Russian teacher Konstantin Tsiolkovsky at the turning of the 19th to the 20th century. For him, spaceflight was a mean for fulfilling his utopian vision of “Cosmism”, which was a philosophical direction, initiated by his teacher Nikolai Fedorov. The Russian “Cosmism” was embedded in a stream of flourishing utopian visions at the beginning of the 20th century in Russia, most of them in the context of utopian socialism. The goals of Russian “Cosmism” can be briefly described as to obtain immortality for all humans and all dead and the colonization of the whole universe. Fedorov saw these goals as the logical consequence from the dilemma of socialism. Real socialism can only be established, if all people who ever lived can benefit from it. Otherwise, there would be inequality between the living and the dead. Spaceflight had the task to collect the particles of the dead in the universe in order to help to bring them back to life and to provide enough new habitats for the resurrected. [1]

Tsiolkovsky describes in his works the extensive use of eugenics and terraforming in order to create a “Super” human, who gradually starts controlling, first the Earth and then the universe.

As strange as these thoughts may appear from today’s standpoint, the influence in the space community is still significant. The birth of spaceflight and the vision of utopia can’t be separated.

CURRENT TENDENCIES

After the rapid development of spaceflight during the cold war, culminating in the moon landings, a rapid decline occurred, which lead to a collective disappointment of many space activists. This “great disappointment” created the split between utopian thinking, which was, from the space activist’s standpoint, manifested by the Apollo program and the actual situation, which turned from human exploration to spaceflight in low orbits around Earth by the “Space Shuttle”. [2]

In the 1970’s, strongly influenced by the “Limit to Growth” debate, induced by the report by the Club of Rome, Gerard O’Neill created a concept of space based solar power generation for Earth and the creation of space colony’s, in order to create a “high frontier”. O’Neill’s concept seems to be a mixture of pragmatic solutions for problems like overpopulation and limits to Earth’s resources, but also includes a strong utopian vision, which is manifested by the space colony’s, which work as social “test tubes”, where “better” societies may develop. [3] This utopian concept was adapted by Robert Zubrin, the founder of the “Mars Society”, where the scenario shifted to the settlement of Mars. As O’Neill, he mentions the concept of an “open” world, to space, which holds unlimited growth and contrasts this vision with a gloomy “closed” Earth based future. [4]

Another tendency, which was proposed by Krafft Ehricke, a German space pioneer, is the evolutionary rationale. The expansion of mankind to space is thought as an evolutionary necessity and therefore the future destiny of mankind. [5] This concept implies a teleological evolutionary concept, where technology and engineering play the role of tools for evolution, in order to fulfil it consciously.

These rationales are frequently proposed within the community as a justification for spaceflight but hold significant potential for critical analysis.

THE DILEMMA OF SPACEFLIGHT

The dilemma and even “schizophrenia” of spaceflight is the apparent discrepancy between its proposed future benefits and the current capabilities. Current spaceflight has reached significant importance for military and civilian use and is integrated into the pool of technologies, which are available for different societies but has by far not reached the capabilities necessary to fulfil any utopian vision. However, many enthusiasts are still focused merely on the utopian vision, which is mainly carried by human spaceflight. The reasons for the development of spaceflight today and in the past were mainly political, scientific and economical. The trans-utilitarian rationale of human spaceflight was not the main reason for its development.

As many technologies were accompanied by utopian visions like flight, nano technology and AI, the accompanying utopian hopes, largely vanished after the introduction and establishment of these technologies. Maybe this is the path, which still lies in front of spaceflight.

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A Semiophere-based Approach for Modelling Pre-semantic Engineering Communication:

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Keywords
Philosophy of Language, Philosophy of Science, Semiotic, Scientific Paradigms, Engineering Paradigms, Underlying Ontology, Semiosphere, Engineering Communication

1. INTRODUCTION

In this reflection we present a communication approach to facilitate the progress of engineering paradigms while they are under the revolutionary phase. We focused the problem on the paradigm's underlying ontology and the stage where semantics is evolving while first models start to be designed, shared and interpreted by the research community. We call this subphase the pre-semantic stage and we sustain that there is some difficulty when new problems, new categories, new modeling languages and new solutions are expressed by using evolving semantics. We claim that it is a relevant philosophical problem because new application and new and legated engineering problems require new models and designs under a fixed semantics as soon as possible. On the other hand, a short evolution could result in an abandoned paradigm. As this problem has not yet been recognized then there is not any solution approaches. However, we can recall that general paradigms' evolution has been described by Kuhn [1], and the scientific social behavior by Bordieau [2]. However, this presemantic subphase has not been described in communication terms. To tackle this problem we present a communication approach based on the semiotic theoretical framework of semiospheres [3].

Therefore, we first present the differences and similarities between scientific paradigms and engineering paradigms arguing the existence of the underlying ontology as structural part of engineering paradigms. We then match the semiosphere concepts with the communicational phenomena of the presemantic stage in an engineering paradigm. In the third part we propose a communicational structure for a modelling language which supports semantic variability for the pre-semantic stage and we show a particular language proposal which complies with this semiotic approach.

2. SCIENTIFIC AND ENGINEERING PARADIGMS

The difference between scientific paradigms and engineering paradigms has been previously argued [4]. While a scientific paradigm represents a fundamental approach for researching - which is basically described by Kuhn [1] – an engineering paradigm constitutes an alternative way of modelling and/or tackling engineering problems. We could say that a practical halo surround an engineering paradigm. Thus while a scientific paradigm has a strong ontology commitment the engineering side has a practical commitment. Under this perspective, it becomes a novel *tool* more than a new and radical philosophical position. The relation between a scientific paradigm and its underlying ontology is explained by Hacking [5]. He says: *I hold that Kuhn has importantly advanced the nominalist cause by giving some account of how at least an important group of "our" categories come into being in the course of scientific revolutions*. That coincides with our use of the concept ontology, i.e. that an ontology is constituted not only by "material" objects, but also by classes, categories, kinds of things and their conceptual relationships**.** At this point we sustain that an engineering paradigm also has its underlying ontology and moreover, the high amount of work around defining, refining and applying the new ontology makes up the mainstream of that paradigm.

We also sustain that each engineering paradigm generates new modelling languages which are based on the underlying paradigm's ontology. In this language new types of solutions or methods for problem solving are proposed.

Therefore, the existence of this underlying ontology, its evolution and dissemination support the evolving process of any paradigm. Thus, the research process of discussing this new ontology and the search of new knowledge resulting in its application are the central activities of the paradigm's mainstream.

During this period the underlying ontology is evolving and, hence, the semantics of terms is also changing, therefore it is reasonable to ask: How can communication take place when semantics is evolving?. How new models and design examples are communicated when their symbols are new and changing?.

In terms of Habermas [6], how can communication be possible when the symbols that mediate the interaction are not intersubjectived ones yet?

3. THE SEMIOSPHERE OF THE UNDERLYING ONTOLOGY

The Bourdieu's theory of fields [2] suggest that the social behaviour of scientific production revolve around a centre where pioneers lead the (sub)discipline (field) and therefore we conclude that they mainly are who propose the initial ontology of a paradigm. However, additional contributions and research discussion could move the field, shifting the centre to other members. We claim that the pre-semantic stage of an engineering paradigm can be seen as a meaning-construction stage which corresponds with the social interaction around thematic axes to build a unified meaning of the new ontology. Given that semiotic studies the process of meaningconstruction, we review this theoretical approach.

Firstly, we refer to Eco [7]. A relevant semiotic idea is to distinguish between communication and the process of making meaning. One of classical semiotic models requires a sign (symbol), an object (element of the ontology) and an interpretant. The interpretant is not the interpreter; it is that which gives guarantee to validity of the sign (normally it is another representation of the same 'object'). In the case of pre-semantic stage the ontology has not been set, therefore, the object is still fuzzy, the sign is new or has a previous semiotic charge (previous meanings) and the interpretant has not yet been established because application domains are still experimental.

Therefore, when a paradigm emerges we have a dynamic semiotic scenario where there is a moving soil for funding the new ideas. Therefore, internal communication such as technical reports, conversations, and papers just tackle a part of all general ideas, (normally in few pages). Thus, only some concepts can reach the rest of the research community under the same meaning. Normally, fuzzy parts will be re-interpreted under the local intensional context, under their own engineering problems and under their own research focus, which means they have different interpretants.
Lotman has introduced the concept of semiosphere to express that mono-semantic systems do not exist in isolation.

These related systems are part of a continuous sphere of meaning namely semiosphere [3]. In this way, we claim that the development of the underlying ontology corresponds to the phenomena of generation of a new semiosphere and constitutes the base of a paradigmatic revolution.
At beginning of the paradigm the new ideas would be the seed of the new semiosphere. These open ideas, almost without sense try to close the concept behind a fuzzy boundary.

Lotman explains [3] that the boundary is the area of accelerated semiotic process and it is represented by the sum of bilingual translatable “filters” which delimitate the internal meaning. Therefore we can say that we have only a new boundary at the early phase of the pre-semantic stage and heterogeneity of possible meanings. At this point, the theoretical approach of semiospheres says that *in peripherical areas, where structures are “slippery”, less organised and more flexible, the dynamic process meets with less opposition and, consequently, develops more quickly*. Then we can say that the new semiosphere grows letting in the centre the dominant semiotic system constituted by a conceptual kernel. At this time we would say that we are in the middle of the pre-semantic stage: we have a set of core concepts with a relative shared meaning and the border where different interpretations, new definitions and proof of concepts shape the expansion of the semiosphere.

Finally, when the pre-semantic stage ends, it is because a formalization of the semantics is produced. In terms of engineering paradigms an example is the production of industrial standards. In the semiospheres’ theory this fact is described in this way: *the creation of meta-structural selfdescriptors (grammar) appears to be a factor which dramatically increases the rigidity of the semiosphere’s structure and slows down its development*.

Other semiotic features and particular attributes described for semiospheras seem to be also applicable ones for the analyzed case, e.g. dialogic communication as the base of meaning generation, ‘invasions’, limitation of penetration, filtering, among other that could be extend our approach.

4. PRE-SEMANTIC MODELLING LANGUAGES

On the light of previous arguments, we claim that a presemantic modelling language would allow the enrichment of the research discussion without stopping the development of the paradigm. It implies the possibility of moving preliminary results to industry.

Also, we sustain that pre-semantic communication can be enabled by a modelling language that goes beyond a particular mono-semantic. We then propose generating a modeling language which considers the semantic internal variability modelling the semiosphere’s structure. Basically it means to consider a core set of categories and to define the conceptual kernel like the stable centre. For representing the unstable portion we propose using a second layer of open language constructors lying on the core concepts. Finally, the possibility of accessing an extra-semiotic space can be done if external language constructors point to their corresponding interpretants. This structure allows the representation of different mono-semantic spaces which can share some core concepts and evolving concepts beyond the centre.

We have starting to experiment this approach with the iStarML language [8] which has been defined by including different variants of a family of software engineering models. It has a set of core concepts and the possibility of specifying new ones in terms of core concepts. To point out we use the feature of XML language [9]for referencing external namespaces for implementing extra-semiotic spaces. We are now working on the specification of configurations which considers reinterpretation rules for neighboured language structures.

Finally, we think we have shown a pre-semantic engineering communication is not only possible but also it can be strongly founded on semiosphere theoretical framework and, moreover its proposal would get benefits for the evolution of engineering paradigms.

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Technology As An Expression of Human Ingenuity

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ABSTRACT

Simple sounding questions are captivating most of the time, one of the similar questions we came across - What is 'Technology'?

We find it simple because we are so attuned to use this word in today's modern world. The common observation is that our current notion of technology confines to machines, equipments and hardware. When searched for specific definitions, what comes as an explanation says that Technology is the knowledge and usage of tools or crafts, the ability to control and adapt to its environment. The Merriam-Webster [1] dictionary offers a definition of the term: "the practical application of knowledge especially in a particular area" and "a capability given by the practical application of knowledge". But, the strict definition or clear conception of 'Technology' is elusive, may be because of the act that term has been used with so many dimensions. Even ancestors of human beings putting leaves around their vital organs would be termed as technology, isn't it?

Thousands of years ago man invented how to make fire [2], however mundane the technology might seem now but creating fire by striking stones or rubbing wood surfaces against each other was the technology to create fire, which helped the ancient mankind to keep themselves warm, to cook their food, to light their caves. During those times the technology to run automobiles was considered foolish. The technology which made airplanes fly was considered impossible. The mankind invented technology to make wheels; wheels made carts and then followed the technology which made automobiles from carts and airplanes from automobiles. With the knowledge to create and the desire to improve human conditions the human beings have progressed from caves to multistoried skyscrapers, from sparks of fire to nuclear energy, from a wheel to space shuttle; but so do the humans have progressed from a stone spear to intercontinental nuclear arsenals.

It's been thousands of years of human civilization; we can certainly say that technology has contributed to improve the human living conditions than worsening it for sure. The human knowledge has become unmanageably vast [3]; every technology created by human race has created numerous and better technologies, each subtler than the rest. The technology which started measurement of distance with hand and foot, invented instruments to measure distance not visible to naked human eye. We think the current generation scientists and technologists need to ask the question to themselves if they know more and more about the less; whether the perspective upon knowing more and more about more and more is on path of getting lost if not lost yet? Is modern world replacing the knowledge and wisdom with mere information?

That's where the core question lies, the technology needs to have some purpose and to be precise a right purpose and a right intent. With over 5,000 years of civilized human world, it's not merely about creation of technology but the use of technology. The technology should ascertain its purpose thereby clarifying its meaning and worth. The technology certainly has given us knowledge and understanding of how tools and processes are to be created to accomplish certain objectives, but it does not answer when to use it and when it would be inappropriate. Every form of technology is likely to harm by its excessive usage based on the basic principle of diminishing utility. The glance of astounding tools and equipments would turn into a disastrous scene if the people who use it are not appropriately equipped with the wisdom to use it. Plato [4] stated that human behavior flows from three main sources- desire, emotion and knowledge. Humans have created technologies with desire warmed with emotions and guided by their knowledge. But, we need to understand one thing that mere knowledge of creation is not enough; the creators and users of technology unguided by the knowledge to use the technology precisely why and when, would be like individuals in a disarray.

So what is the right perspective on creation and use of technology? The right perspective has to be the correct fit which works best for the optimum results, but this 'correct fit' or 'golden mean' is not like a mathematical mean, an exact average of two precisely calculable extremes in terms of purpose for the creation of technology and use of technology. It is bound to fluctuate with collateral circumstances of each situation, but what would be wisdom on part of creators and users of technology is to discover it only with mature and flexible reason. The technology in itself can not improve or worsen the human living condition. The technology does not exists on its own; it has to have some purpose and being overtly optimistic good purpose. The only purpose of technology is to simplify, amplify and magnify the human creativity and ingenuity [5]. All the technologies should be embedded in the social context in which they operate and should have the right intent of use. We would like to illustrate this point by citing example of Jugad [6] the transportation vehicle spotted in northern rural part of India, developed by the local mechanicians. These vehicles are used for transportation of agricultural products and commutation of people. Jugad is developed by using the motors used for water pumps and can match up any regular tractor or pick-up van in terms of capacity, fuel efficiency and speed. It costs slightly more than a motorcycle. None of the local mechanicians are qualified engineers but the technical skills match up to the need for a commutation technology for the rural population who cannot afford to buy a tractor or pick-up van, delivers a perfect technology in form of Jugad perfectly embedded in social context. Another illustration of technology being entrenched in social context would be use of washing machine technology in rural India to make Lassi, a milk product, one of the favorite drinks in India. It is well documented that across the Punjab rural expanse, washing machines churn loads of lassi to quench the thirst of the thousands. Shops and big rural households have found an innovative use for washing machines technology; to help churn their ubiquitous health drink. We can have a look at converse perspective as well; in India we have technology to cut open a coconut, particularly in western coastal part of India. But, it would be surprising to notice that the technologically advanced country in Asia, Singapore, does not use this kind of technology which would make the job of splitting open the coconut much simpler. In the case of Jugad and use of washing machine to make Lassi, the purpose of technologies is well defined but as a matter of human ingenuity those technologies have been used for different purposes which are embedded in the social context of rural India. While, even with the case of coconut opener, the purpose of technology is well defined, but still there are not takers of this technology in a technologically advanced country like Singapore, why? That's because this technology does not fit in the social context of Singapore. Though, this technology would help splitting coconut easier, may be its not accepted in Singapore because people there do not value its utility. This explains why we need to emphasize the aspect of technology being embedded in social context. All the superior technologies we have created would not better our lives if we lack the intelligence to use those technologies. The more we are multiplying the technologies the less certain and general is the use we are able to make of them. The task of creators is very crucial in keeping the social and moral fibers intact while creating every other small or big technology. Perhaps, we must understand that the technologies created by us must comply with human nature and omnipotent environment.

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Simulating Time

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In a famous article entitled "Simulating Physics with Computers", Richard Feynman discusses the possibility of simulating quantum systems. The question of simulating time is also addressed. It is stated that, in simulations performed by cellular automata, time is not simulated but is rather imitated by being hidden behind the state to state transition. Simulating time and in particular the emergence of relativistic space-time can be important for enhancing our understanding of modern physics. In the present paper we introduce the notion of the observer that is part of the simulated system. For this kind of observers we show that time and relativistic space-time (in the sense of special relativity) can emerge if the computation rules used by a cellular network obey certain conditions. Thus, by taking into account the point of view of such observers, we can simulate the emergence of time, including relativistic space-time. This kind of simulation could help us enhancing our interpretation of certain "paradoxes" of modern physics.

EXTENDED ABSTRACT

In the present article we treat the question of simulating physics and more particularly simulating time. This question was addressed in Richard Feynman's famous article "Simulating Physics with Computers" [1]. The article proposes the idea of a computer that could act as a quantum mechanical simulator [2]. This idea was one in a series of key events leading to the idea of a general quantum computing device [2]. Beyond its principal aim, related to the simulation of quantum systems, it also addresses some other issues concerning the simulation of physical systems, including time simulation. The following quote from [2], is a concentrate of most questions we are treating in the present paper. The parts underlined and numbered by us, are useful for highlighting these questions:
"In order to simulate time, the first assumption that Feynman makes is that the time is discrete [1]. According to him, in cellular automata, time is not simulated, but is rather imitated by being hidden behind the state to state transition [2]. He explores ways to simulate time in cellular automata rather than imitating it. In particular, he shows an example in spacetime domain [3]. In his example, the state si at the space-time point i is a given function Fi(sj , sk, . . .) of the state at the points j, k in some neighborhood of i: Si = Fi(sj, sk, . . .). If Fi is such that it only contain the points previous in time, we can perform the computation in a classical way.

However, if Fi is a function of both future and the past, would there be an organized algorithm by which a solution could be computed? Even if the function Fi is known, this task may not be possible."

Some other quotes from [2] "Local probabilities cannot explain what is obtained in practice. The two photons are in an entangled state, and measuring one determines the result of measuring the other "4. "Two or more objects in an entangled state have to be described with reference to one another, even if they are physically separated. …, it is this fact that is used by Feynman in an example to show how a local probabilistic classical computer cannot simulate quantum mechanics. " 5 and from Feynman's article itself [1] "I would like to have the elements of this computer locally interconnected, and therefore sort of think about cellular automata as an example (but I don't want to force it). But I do want something involved with the locality of interaction. I would not like to think of a very enormous computer with arbitrary interconnections throughout the entire thing."6 are also useful for introducing the questions treated in the present article.
The questions/assumptions/claims stated above in the underlined text (quotes 1,2,3,4,5,6) are fundamental for physics simulation and may also help enhancing our understanding of physics. The hope that simulation could help enhancing this understanding is actually the principal reason for which Feynman is interested in simulating physics as expressed
in [1]: "There are interesting philosophical questions about reasoning, and relationship, observation, and measurement and so on, which computers have stimulated us to think about anew, with new types of thinking. And all I was doing was hoping that the computer-type of thinking would give us some new ideas, if any are really needed."

The aim of this paper is to revisit these questions by paying particular attention to the role of the observer, as her/his careful choice may bring new light on some of the "paradoxes of modern physics. To give a first example about the importance of the choice of the observer, let us consider the claim "time is not simulated, but is rather imitated by being hidden behind the state to state transition" (quote 2). This claim is valid if we consider that the simulated system is observed by an observer external to it (e.g. the persons that created simulation). For instance, in synchronous cellular automata where the computations of all the cells are paced by a clock signal, the state-transitions of the cells are paced by this clock signal. As this clock signal corresponds to the flow of the own time of the external observer, this observer will perceive the state transitions to follow the flow of his/her own time. Thus, we can not talk about time simulation. However, if the goal of the simulation is to try to understand our own world, the observer of the simulated system should be in the same position as we are when we observe our world. That is, the observer must be internal to the simulated system, meaning that she/he is constituted by the same elementary entities as the ones forming any other object of the simulated system, and is using observation/measurement means constituted by such elementary entities.

Then, by considering the point of view of the observers that are part of the simulated system (referred also hereafter as simulated universe), we find that the term "time simulation" is fully justified, as under certain necessary and sufficient conditions time emerges for these observers. This time, internal to the simulation, is governed by three principles:
- the principle of its independence from our time(or external time),
- the principle of its qualitative emergence (determined by the invariance of the rules that govern the computation of the states of the system- laws of physics), and the principle of its quantitative expression (determined by the particular form of

the laws that govern the computation of the states of the simulated system).

These conclusions are important because they suggest that we should be able to simulate the emergence of time by simulating the laws governing a physical system. This also applies to space-time (mentioned in quote3). We indeed find that, emergence of relativistic (Lorentzian) space-time or Galilean space-time will be observed by the observers being part of the simulated universe, if the computation laws obey certain conditions.

The question of non-locality exhibited by entangled particles (quotes4,5,6) is also related to the question of time, as measuring one of the entangled particles determines instantaneously (i.e. in nil time) the result of measuring the other particle. Another issue concerns the communication problem between distant entangled particles. The exclusion of arbitrary interconnections throughout the entire thing (quote 6), imposes local probabilistic computer. But such a computer can not treat entanglement (quote5.). In section 3, we propose to treat entanglement by changing some of the assumptions considered in [1]. On the one hand, the point of view of the observers that are part of the simulated universe can allow eliminating the contradiction between the instantaneous "communication" between entangled particles and the finite time of communication between the elements of classical computing systems. On the other hand, considering Hertzian communications based on tiny radios built on a single CNTB [3] could provide a solution to the interconnections strangle. Then, on the basis of these ideas, we discuss a practical approach for simulating entanglement.

Finally, the assumption of discrete time (quote1) is necessary if we consider digital computers. However, if the time in our world is not discrete, then, in theory, truly analogue computers could be built and used for simulating physics (or at least some parts of modern physics). Thus, the question of discrete or continuous time should not be considered as a fundamental limitation in simulating physics, thought in some situations, digital computers operating with discrete time may simplify the analysis. In particular, our treatment of relativistic time is done in a manner that is valid for both discrete and continuous time.

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EXPERIMENTAL PARAMER VARIATION IN SOCIAL ENGINEERING

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In his book *What Engineers Know and How They Know It* (1990), Walter G. Vincenti carried out a methodological analysis on engineering arguing that Experimental Parameter Variation, EPV, is one of the most conspicuous methods employed in this discipline. His work was based on the engineering work done during the first two decades of the twentieth century to create new and more powerful aircraft propellers. The available theory did not provide enough information to know what would be the optimal propeller: its size, form and material. There was now causal law establishing the optimal relation between form, weight and material to obtain the wanted effect. No precise predictions could be made. Numerous experiments were then performed varying in a systematic way not only materials, forms and sizes but also external conditions like air velocity, turbulences and so on, to find out which would be the optimal performance and the optimal propeller.

Thus, EPV consists of systemically varying the parameters of operation and measuring the resulting variations to determine the optimal performance of materials, processes or devices. Note that EPV is particularly required when propositional knowledge (know-that) captured in theories or theoretical models is not enough. EPV is an experimental engineering method where practices play the main role. Being a methodology EPV is not a set of rules about how to infer but about how to do things.

In science I suggest to distinguish between *factual* and *counterfactual* methods and I place EPV in the latter. While factual methods are concerned with how the world actually is (measuring, registering, predicting), counterfactual methods deal instead with how the world might be by bringing about and stabilising new phenomena and their laws and by introducing unknown artefacts into the actual world. In factual methods predictions, explanations or analogies are carried out on the basis of *what is the case;* that is, on *de facto* causal laws; in counterfactual engineering methods the content of the reasoning is about possibilities not about actualities. Causes and effects have both to be brought about. Predictions are not possible since there is no causal law is yet available. Counterfactual methods imply, I argue, different logics, metaphysics, semantics as well as different epistemic norms and analytical tools. One the most appealing and seemingly contradictory features of engineering methods is that they provide positive methods to approach metaphysical endeavours. Quite distinctively engineering is a metaphysical scientific enterprise.

Empirical science is commonly understood as commented to reality as it appears now. Metaphysical considerations were firmly rejected by positivisits and empiricists alike unless opearationalist means were practicable. Engineering and policy making, however, demand counterfactual methods which are rather committed with how the world might be. In social sciences, the need for counterfactual methods is particularly evident when new reforms or economic and social changes are introduced as well as when new economic orders are intended or implemented. When counterfactual methods are employed social science becomes social engineering. To illustrate this I want to show how the method of Experimental Parameter Variation can be used to understand and systematise what experimental economics do when new policies or market mechanisms are needed. It is also my interest to build a methodological bridge between natural science engineering and social engineering showing the similarities between the two expanding the scope of EPV helping experimental economists and philosophers of economics to understand experimental practices which otherwise are overlooked, poorly analysed and systematised and, quite often, still understood and analysed from the perspective of the theoretical, pure science, tradition in science.

Engineering ascending auctions: Ascending auctions were a new economic device successfully implemented in the eighties to allocate licences to use portions of the spectrum for radio communication, telephones, etc. In a simultaneous ascending auction several markets would be open at the same time allowing bidders 1) to participate in all of them at once and 2) place continuous offers, combining them, withdrawing and even buying them again until the buyer is satisfied and the market is closed, which would occur until no offer is put forward. Three main data were essential to implement this kind of auction about which the available theory had no answer: the optimal increment to fix the minimum bid after each round, the optimal number of rounds, and for how long cycles of purchase-withdrawal-repurchase of licences would go before disappearing. To find out these two optimals and the duration of cycles it was crucial to attain an efficient distribution of licences, defined as that one providing the highest profits for the government by allocating licences to those bidders who value them the most, and indeed such a distribution was in the end accomplished yielding twenty-three billion dollars as revenue for the federal government of The United States.

Charles Plott, experimental economist, and his team determined the optimals of increments and rounds, and the duration of cycles by systematically varying the relevant parameters of operation. This methodology however was not reported by Charles Plott and philosophers of economics like Francesco Guala (*The Methodology of Experimental Economics*, 2005) who rather engaged in detailed, at times anecdotic, report of the case ending up with a descriptively rich but unsystematic account. By trying determining the optimal increment of bids it was observed that large increments above the highest standing bid may eliminate bidders too quickly inducing conditions to get an inefficient final distribution of licences. After several variations the parameter was finally determined between five and ten percent of increment above the highest standing bid from the last round: enough to speed the action up and not too big avoiding in this way demand killing and inefficiency. Thus, through EPV an increment between five and ten percent was found to be the optimal.

Given the lack of laws each variation was carried out on counterfactual basis tackled experimentally: what would happen if the increment were of 1%, 2%,…10%, 11%,…20%, 21%, etc. until the optimal was found out and the pursued phenomenon observed: the shortest possible auction with no demand killing. Finding out the optimal of every parameter was therefore essential to accomplish an efficient distribution and EPV played a crucial role as experimental methodology providing data not obtainable through theoretical reasoning. The experimentally determined optimals became pieces of a larger device assembled to bring about a new economic market mechanism: the ascending auctions. Are social engineers justified in entertaining beliefs about non-existent devices and artefacts? Operationalist means seem not be feasible for this new economic device while it is been designed and seriously entertained as engineering project. Empiricist criteria would render this and other engineering beliefs and practices as meaningless since there is no direct or indirect means to get empirical input about the devices being projected. Engineering methods however provide the grounds to entertained those beliefs and practices in a scientific way. A full account on this requires, I argue, a pragmatic semantics of possible worlds.

Engineering work is often overshadowed by the overemphasis made on theory and on methods related to theories and on propositional knowledge, which has been a common practice in the philosophy of science. Vincenti's work along with the work from philosophers like Ian Hacking (*Representing and Intervening*, 1983) and Nancy Cartwright (*Hunting Causes and Using Them*, 2007) among others urge for a philosophical reassessment of experimental and engineering methods. Between abstract laws and concrete laws, between theory and the ultimate concretisation of causal claims in devices and artefacts, there is a significant methodological gap often neglected in the philosophy of science. This gap includes not only experimental methods but also engineering methods, which in economics and socials sciences are crucial for the design and implementation of public policies. To the extent that these methods are made explicit, assessed and articulated though methodological analysis we may expect not only a different image of contemporary science but also improvements in the making and application of public policies and in the life of those affected such policies. The vindication of engineering methods in social sciences is aimed at recovering a more active role for the society in the making of policies and a more reliable governmental action aided by these methods. In this sense philosophy of engineering provides not only a different image of science but it also becomes an anthropological philosophy expanding the range of social and technological possibilities for the human species.

How could a robot have qualia?

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The purpose of this talk is to discuss whether a robot with a particular set of features can be said to have an 'inner world', something that can be taken to be a critical feature of consciousness, and whether this inner world is subjective in the way that the inner world of humans is subjective. It will be argued that perceptual simulation implemented in a robot may not in itself be sufficient but if some, technically rather trivial, additional mechanisms are added, the robot would have an inner world. If one also adds a mechanism for comparing perceptual simulations, so that the robot could determine whether two (simulated) perceptions are similar or dissimilar, a case can be made that the robot also has qualia.

The simulation theory.

I have has previously argued that the mechanism underlying the appearance of an inner world in humans is an ability of our brains to simulate behaviour and perception. This theory is based on three assumptions about brain function. Firstly, it is suggested that an action can be simulated by activating motor structures in the brain (mainly the frontal lobe, basal ganglia and cerebellum) roughly as they would normally be activated during an overt action, except that the final output from the primary motor cortex is suppressed. Simulated actions are essentially low amplitude behaviours.

The second, and in the present context most important, assumption is that perception of an external stimulus can be simulated by internally elicited activation of the sensory cortex in a way that is similar to the way it would have been activated by normal perception of an external stimulus. Thus, if my visual cortex is activated in a way that is sufficiently similar to the activity that occurs when I am looking at a real tree, the neural processes that follow will also be similar. Thus, the neural activity that normally underlies seeing a tree will occur, regardless of how that activity is elicited and regardless of whether any tree or tree-like object actually exists. Although seeing a tree would normally entail the existence of a tree that is seen, the simulation process suggests that there is a sense in which we can be said to see a tree even if there is no tree to be seen. Another way of putting it is to say that simulated perception can explain why there *appear* to be such objects in spite of the fact that there are good reasons to deny their existence.

Thirdly, we assume that there is an anticipation mechanism such that early stages of both overt and covert actions can elicit perceptual simulation of their normal consequences. A consequence of these mechanisms is that a simulated action can generate simulated sensory activity, which in turn can function as a stimulus for new simulated behaviour and so on. Thinking, on this view, is essentially a simulated interaction with the external world.

These three mechanisms allow an organism to simulate interaction with the external world. It is argued that such simulation explains the appearance of an inner or "mental" world. The simulation hypothesis suggests that we have an inner world in the sense that we can experience a world through simulated perception even though there are no actual objects corresponding to the experienced objects. A patient, who has lost a limb, can still have a clear perception of it and can have severe pain which seems to emanate from a so called 'phantom' limb. The phantom limb is quite real to the patient, and talking about it as if it really existed is difficult to avoid, but could be seriously misleading if someone was led to believe that the phantom limb was made of flesh and blood.

A robot implementation of the simulation theory.

A robot has previously been designed by Dan-Anders Jirenhed and Tom Ziemke in which perception can be simulated. The robot, here called *K*, is a simulation of a simple Khepera robot. *K* moves around in a simple environment guided by input form visual sensors. It is controlled by an artificial neural network and learns to navigate in the environment so that it avoids collisions. It also acquires associations between movements and consequent visual inputs, that is, it learns to predict the consequences of movements. After training, the robot can move around successfully without collisions *while only using its internally generated sensory input, the predictions,* as a guide. Thus, the robot may initially learn that as it moves forwards and sees an obstacle approaching, it should move sideways. When it later moves forwards, its anticipation mechanism will make it see the obstacle approaching *even when the sensors are turned off* and this imagined perception of the obstacle will elicit the appropriate avoidance behaviour.

Does the robot have mental objects?

From the point of view of the module controlling the movement, the situations where the robot is using input from the external world and where it is using simulated input, are quite analogous: in both cases it "sees" the obstacles and avoids them. There is a clear sense in which the robot can be said to see and react to things that only exist within itself - "in its mind". It is surely reasonable to say that the robot has the core of an inner reality.

To take an analogy to the phantom limb case, if a mechanical object is designed to respond in a certain way to a certain input, it is usually possible to bypass the input and insert a 'fake' input before the response-generating mechanism. For instance, an external signal could make the speedometer of a car display a speed when the car was actually standing still. This is also true if the response is a verbal report of the input. My computer can perceive which key is being been pressed on its keyboard and can display a report on the screen 'I notice you just pressed *X*. It would not be difficult to bypass the keyboard and send a similar signal to the central processor, tricking it into displaying the same message. The computer would then be simulating the observation of *X* being pressed, but we should not be tempted into saying that there is an 'image' of *X* being pressed or a mental representation of such a press in the CPU.

There are of course several limitations in the repertoire of the robot that make comparisons with living organisms strained.

For instance, the robot can only use the simulated perception for one type of response. An important feature of human perceptual simulation, indeed the reason for its existence, is that it can be used in different contexts for different kinds of behaviour. But there is no reason to suppose that this and many similar abilities can not be added to the robot.

What about qualia?

There is a sense in which *K* can see an object *X* even if there is no *X* actually exists, because the process of seeing can occur in the absence of *X*. But is this really seeing? *K responds* to *X* or a simulated *X*, but sceptics could claim that a crucial element is missing, namely the *subjective experience* of (seeing) *X*.

Behind this objection lies an assumption that humans not only respond when they see something, but that the responding is accompanied by an additional element, the *experience* of *X* or *X*-like *qualia*. There is 'something it is like' to see *X,* that humans have and that we have not demonstrated in *K*.

Two extensions of *K* might make it easier to accept that it too could me made to have this additional element.

First, when a human being perceives something, many responses arise, most of them covert. Seeing an apple will not only make you want to eat it. It will elicit covert saying the word 'apple', touching it, grabbing it, envision yourself eating it etc. Enabling K to have many responses to a single perception would not be too difficult to achieve.

Secondly, the intuition that 'there is something it is like for *K* to see *X'* might be made stronger if *K* could make similarity judgments. Suppose, for instance, that *K* could judge the similarity between objects *X* and *Y*, by comparing the sensor activations when the two objects were perceived. If this was possible, it would be a small step to assume that *K* could also compare internally simulated perceptions and make judgments about the similarity between imagined cases of *X* and *Y.* If this was done, it could be said there may indeed be 'something it is like for *K* to see *X*', namely seeing *Y*.