*f*PET-2010

2010 Forum on Philosophy, Engineering & Technology

In Cooperation with

the Society for Philosophy and Technology (www.spt.org),
the IEEE Society for the Social Implications of Technology (www.ieeessit.org),
the Liberal Education Division & the Technology Literacy Constituent Committee of the American Society for Engineering Education (www.asee.org),
the International Network for Engineering Studies (www.inesweb.org),
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Abstracts

of the 2010 Forum on Philosophy, Engineering & Technology

Colorado School of Mines
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Welcome to fPET-2010

Greetings and welcome to the 2010 Forum on Philosophy, Engineering, and Technology at the Colorado School of Mines in Golden, Colorado!

The 2010 Forum on Philosophy, Engineering, and Technology, or fPET-2010 for short, is an outgrowth of two previous meetings: the 2007 Workshop on Philosophy and Engineering (Delft), the 2008 Workshop on Philosophy and Engineering (London), as well as a track on "Reflective Engineering" connected to the 2009 meeting of the Society for Philosophy and Technology (Enschede). These meetings have been instrumental in building intellectual community and mutual understanding among philosophers and engineers, and fPET-2010 is designed around a similar purpose. Our hope is that through the multiple opportunities for interaction, both formal and informal, that will take place in the day and a half of this meeting will serve to continue to advance this community and along with it, galvanize research in the exciting and emerging area of the philosophy of engineering.

There are many we have to thank for the thoughtful work they have done to plan, organize, and bring fPET-2010 to fruition. First, we are deeply indebted to Carl Mitcham and to his offer of the Colorado School of Mines as a location for this meeting.

Second, we would like to take this opportunity to publicly thank and express our appreciation to those members of the fPET-2010 steering committee and program committee whose ideas and efforts have been instrumental in shaping this meeting.

As fPET's mission statement indicates, one of the goals of this meeting is to bring together professional organizations of engineers and philosophers. This time around fPET-2010 was blessed with the cooperation of the following organizations: the Society for Philosophy and Technology (`http://www.spt.org`), the IEEE Society for the Social Implications of Technology (`http://www.ieeessit.org`), the Liberal Education Division (`http://www.calvin.edu/academic/engineering/aseeled/`) & Technology Literacy Constituent Committee (`http://www.hope.edu/academic/engineering/aseetlcc/`) of the ASEE, the International Network for Engineering Studies (`http://www.inesweb.org`), & the Engineering Philosophy Committee of the Structural Engineering Institute (SEI) of ASCE (`http://www.seinstitute.org`).

In the course of putting this meeting together, a few individuals have played key roles, and we would like to give them our sincere thanks as well. Xavier Llorà performed yeomen service as Technology Chair and webmaster and to him we are very thankful. We are also grateful to Jill Savage, Program Assistant to the Hennebach Program in Humanities at the Colorado School of Mines, for her superb support in handling the many details associated with local arrangements. The cover art was designed by Brent Wagner, a student at University of Illinois, and to him we say thank you and a job well done.

Once again, welcome to fPET-2010, thank you for your participation, and may you enjoy a most productive meeting.

Dave Goldberg
Diane Michelfelder
Co-chairs, fPET-2010

fPET-2010 Schedule

Sunday, May 9th

4:00PM - 5:00PM — Registration — Room: Ben Parker Student Center, Second Floor

5:00PM - 5:15PM — Welcoming Remarks — Room: Ballrooms C&D, Ben Parker Student Center

5:15PM - 6:30PM — Opening Keynote Address — Room: Ballrooms C&D, Ben Parker Student Center

Beyond Satisficing: Design, Trade Offs and the Rationality of Engineering
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6:30PM - 8:00PM — Opening Reception — Room: Ballrooms A&B, Ben Parker Student Center

Monday, May 10th

7:30AM - 8:00AM — Registration — Room: Ben Parker Student Center, Second Floor

8:00AM - 8:15AM — Announcements — Room: Ballroom A, Ben Parker Student Center

8:15AM - 9:45AM — Concurrent Session I-A — Room: Alpha

Chair: *Ibo van de Poel (TUDelft)*

8:15AM - 9:45AM — Concurrent Session I-B — Room: Beta

Chair: *Carl Mitcham (Colorado School of Mines)*

8:15AM - 9:45AM — Concurrent Session I-C — Room: Gamma

Chair: *John P. Sullins (Sonoma State University)*

8:15AM - 9:45AM — Concurrent Session I-D — Room: Delta

Chair: *Jill Savage (Colorado School of Mines)*

10:15AM - 11:45AM — Concurrent Session II-A — Room: Alpha

Chair: *Sarah Bell (University College London)*

10:15AM - 11:45AM — Concurrent Session II-B — Room: Beta

Chair: *Elaine Englehardt (Utah Valley University)*

10:15AM - 11:45AM — Concurrent Session II-C — Room: Gamma

Chair: *David E. Goldberg (University of Illinois)*

11:45AM - 1:00PM — Lunch & Lunchtime Plenary Speaker — Room: Ballroom A, Ben Parker Student Center

1:00PM - 2:30PM — Concurrent Session III-A — Room: Alpha

Chair: *Darryl Farber (Pennsylvania State University)*

1:00PM - 2:30PM — Concurrent Session III-B — Room: Beta

Chair: *Jen Schneider (Colorado School of Mines)*

1:00PM - 2:30PM — Concurrent Session III-C — Room: Gamma

Chair: *Kerri Stone (Colorado School of Mines)*

3:00PM - 4:30PM — Concurrent Session IV-A — Room: Alpha

Chair: *Joseph Pitt (Virginia Tech)*

3:00PM - 4:30PM — Concurrent Session IV-B — Room: Beta

Chair: *Eric Katz (New Jersey Institute of Technology)*

3:00PM - 4:30PM — Concurrent Session IV-C — Room: Gamma

Chair: *Diane Michelfelder (Macalester College)*

4:30PM - 5:00PM — Kaizen (Suggestions for Improvement) — Room: Ballroom A, Ben Parker Student Center

5:00PM - 6:30PM — Concurrent Session V-A — Room: Alpha

Chair: *Elaine Englehardt (Utah Valley University)*

5:00PM - 6:30PM — Concurrent Session V-B — Room: Beta

Chair: *Cherrice Traver (Union College)*

5:00PM - 6:30PM — Concurrent Session V-C — Room: Gamma

Chair: *Wade Robison (RIT)*

6:30PM - 7:30PM — Closing Reception — Room: Ballroom A, Ben Parker Student Center

fPET-2010 Abstracts

Abstracts

Beyond Satisficing: Design, Trade Offs and the Rationality of Engineering

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Design is a complex process whose input is an abstraction, typically an incomplete specification, and whose output is concrete: one particular, new, object, broadly construed, that needs to be to be realized. At the heart of this process is the sub-process of making trade-offs, in which the incomplete specification is transformed into just one realization out of many possible alternatives. It is in the distinctive and fundamentally unscientific making of trade-off decisions that the rationality of engineering reasoning is most clearly revealed, and revealed to be different from the definition of rationality that has dominated Western science, mathematics and philosophy since Plato. Engineering is thus caught up in the tension between knowledge and know-how in Western culture, between reason and will, and between the Sophistic, Sceptical and Pragmatic traditions in Western philosophy and the Rationalist, Empiricist and Idealist traditions.

How Analytic is Systems Analysis? A Survey of Major Types of Technical Analysis from the Standpoint of Philosophic Analysis

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Analysis is central to philosophy and to engineering and technology. Engineers perform systems analysis, root cause analysis, process analysis and forms of software analysis such as object oriented analysis. Philosophers since at least Aristotle, who codified Aristotelian logic in his Analytics, continuing through to contemporary analytic philosophers have regarded analysis as central to philosophic method and to reasoning itself. When the two millennia of philosophic reflection on analysis are brought to bear on the major types of analysis central to engineering and technology, what can we learn? Are settled methods of technical analysis incomplete when considered from a philosophic perspective? Or does the real-world experience and success of major modes of technical analysis suggest valuable insights into analysis as a form of reasoning that would inform debates amongst philosophers concerning analysis? These are the questions that are pursued in this paper.

While analysis has always been indispensible to philosophic method and to philosophic understanding of reasoning itself, it has been understood in different ways by different philosophers. Beaney categorizes the three major conceptions of analysis in philosophy as regressive, decompositional and transformative. Regressive analysis begins with intuitions and sense observations that are “first for us” and analyzes them to reveal their first principles that are “first by nature”. Decompositional analysis, the resolution of complexes into their simple components, is most associated with analytic propositions in which the meaning of the predicate is contained in that of the subject. More recently, propositions were analyzed into a logical form that facilitated a subsequent decompositional analysis. Many philosophers have combined these elements in their conceptions of analysis.

Modern engineering and technology received much of their essential foundations as a result of a decompositional approach to knowledge introduced in early modern science and philosophy. The decompositional approach to knowledge begins most clearly with Leibniz, who converted the propositional structure of Aristotelian logic (subject is predicate) into an equation (subject = predicate), thus enabling computational treatments of knowledge using a formal logic. This conversion was grounded in Leibniz’ decompositional view of analysis and knowledge that “in every affirmative true proposition, the notion of the predicate is contained in some way in that of the subject, praedicatum inest subjecto. Or else I do not know what truth is.” The mathematical logic constructed by Leibniz on this analytic foundation was central not only to calculus but to the first computers.

One would thus expect to find decompositional analysis, perhaps preceded by a transformative analysis, in all major types of technical analysis employed by engineers. This paper argues that, in fact, regressive analysis is central to technical analysis in practice. The features of regressive analysis – a realist approach to sense observations, beginning with given sense observations that are first for us, working back from these observations to their underlying causes in nature, the often surprising counter-intuitiveness of what is revealed to be first by nature – are found in major types of technical analysis. Furthermore, technical analysis is often critiqued as done poorly when it is a decomposition of a given process, incident or domain into its component steps or parts, and documentation of such components, lacking any real analytic insight. This paper surveys systems analysis, process analysis, root cause analysis and some major forms of software analysis in support of this argument.

Technical analysis resembles regressive philosophic analysis more than decompositional and transformative approaches to analysis because technical activity – writing software, designing circuits, etc – are intentional phenomena, as is also argued by Cantwell Smith. They presume a more direct, realist relationship between mind and world than is assumed in decompositional and transformative analysis, but that is central to regressive analysis. They thus challenge modern notions of analysis in analytic philosophy to account for technical analysis by developing a more comprehensive understanding of analysis. The paper concludes with mention of modern philosophers who have called for a more comprehensive understanding of analysis, including Bolzano.

The Conflicts Hidden In The Empirical Turn?

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The Empirical Turn (ET) in the Philosophy of Technology claimed that “philosophical reflection on technology should not start from preconceived and simplistic images of technology; instead, philosophical reflection should be based on empirically adequate descriptions reflecting the richness and complexity of modern technology”.(Kroes & Meijers, 2000) The key of the ET is that there is not a sharp distinction between the analytic and the synthetic. This is what Quine had argued in his “Two Dogmas of Empirism”.

Quine argued that the dogma of reductionism supported the other dogma of a sharp distinction between the analytic and the synthetic.

“The dogma of reductionism, even in its attenuated form, is intimately connected with the other dogma: that there is a cleavage between the analytic and the synthetic. We have found ourselves led, indeed, from the latter problem to the former through the verification theory of meaning. More directly, the one dogma clearly supports the other in this way: as long as it is taken to be significant in general to speak of the confirmation and infirmation of a statement, it seems significant to speak also of a limiting kind of statement which is vacuously confirmed, ipso facto, come what may; and such a statement is analytic.”(Quine, 1963)

When we accept ET, we must be against the dogma of a sharp distinction between the analytic and the synthetic. When we accept there is not a sharp distinction between the analytic and the synthetic, we must be against the dogma of reductionism. So, I think, the holistic perspective is prior when we reflect on technology and engineering.

However, when we accept the holistic perspective and the ET at the same time, here come two problems.

(1) According to ET, we must open the black box of technology when we are reflecting on technology and engineering. I take it as that we use the reductive methods to decompose the technology as an integral one to the technology as the details of parts and processes in engineering design. The focus is the part, I mean, that is reductive method. But, if we accept the holistic perspective is prior, the focus is the whole, I mean, that is holistic method. Could the focuses are the reductive method and the holistic method at the same time? I think they are conflicting.

(2) If we assume that it is not conflict between the prior holistic method and the reductive method to open the black box of technology, there is no conflict. But, how does the assumption work in the practices of technology and engineering design? Is there a case to defense the assumption? Is there some method to defense the assumption? Or, is there a context that the reductive method is the special form of the holistic method?

If we accept the holistic perspective is prior but do not open the black box, I think it will lead to the social criticism again. That is not what we want.

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Value Sensitive Design: Four Challenges

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In recent years, various authors have argued for incorporating values of ethical importance into engineering design (Friedman and Kahn 2003; Flanagan, Howe, and Nissenbaum 2008). We want cars that are safe and sustainable. We want internet search engines that are transparent in how they gather information, that have no systematic bias towards certain information, that respect our privacy, et cetera. Value sensitive design is a laudable enterprise and it is something that designers have been doing, to some extent, all the time. Nevertheless true or successful value sensitive design raises a number of challenges. I will discuss four of such challenges: (1) How to determine what values to include in an engineering design project? (2) How to make these values bear on the design process? (3) How to make choices and tradeoffs between conflicting vales? (4) How to verify whether the designed system embodies the intended values?

These challenges may seem practical in nature, but I will argue that each of them is related to one or more deeper philosophical problems. My aim is to clarify these problems, and to make some suggestions how we can deal with them. My aim is not to deliver a clear-cut methodology for value-sensitive design but rather to contribute to the reflective awareness of engineers so that they recognize and can better deal with the mentioned issued.

(1) The question about what values to include in an engineering design project is partly a question about how to identify relevant values given a certain design project. In general, values can be based on such sources as the design brief, values hold by the designers and the engineering profession, values expressed by users and other stakeholders and more general social values expressed for example in codes of ethics, technical codes and standards or in relevant laws. Just identifying values is not enough, however: designers also need to answer the normative question what values are worth pursuing in design. Should they focus on intrinsic rather than instrumental values? Can we somehow distinguish ‘mere’ values from ’real’ values? I will argue that values are more than individual preferences; they imply – at least implicitly – a claim to something that is more generally good. Following recent literature on value in philosophy (Scanlon 1998; Raz 1999; Dancy 2005), I will further suggest that values typically correspond with reasons for certain attitudes or actions, in our case with respect to design.

(2) Making values bear on design requires bridging the gap between the world of ideas and the material world, or bridging the gap between philosophy (and other humanities and social sciences) and technology. I will argue that this is exactly what engineers usually do in design, although they often do not explicitly consider values in doing so. Building on an analogy with how designers usually translate desiderata in designs, I will distinguish four kinds of activity with respect to values that are needed to make values bear on design: 1) specifying values (by expressing them in functional requirements), 2) translating values (in technical features and heuristics), 3) embodying values (in material configurations) and 4) operationalising values (to make them measurable so that they can be used to compare different (concept) designs).

(3) Making tradeoffs between values, or design criteria, is a common procedure in engineering design. I will argue, however, that engineers here tend to neglect what philosophers have called the incommensurability of values (Raz 1986; Chang 1997). Two or more values are incommensurable

if they cannot be measured on the same scale. Incommensurability may arise from the fact that it is impossible or at least inappropriate to cancel out loss in one value domain by benefit another domain (For how much money are you willing to betray your friend?). Incommensurability precludes certain optimizing approaches to value conflicts but it does not make dealing with value conflict necessarily irrational.

(4) Value sensitive design presupposes that it is somehow possible to embody values in design, but is it? One counter argument seems to be that the same technology implemented in different social contexts may well support different values. But differently designed technologies (with the same function) in the same user context may also realize different values. It thus seems that values are embedded in the combination of a technology and its use context. This implies that designers need to anticipate on user contexts in the design process and that the user context should be accounted for in verifying whether a certain design supports certain values.

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Engineered Artifacts

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It has been argued (Kroes 2009) that technical artifacts are distinct from natural and social artifacts, and that they have a dual nature comprising both a physical description and a functional description, which are coupled together through human intention. This paper explores the question of whether technical artifacts can be further differentiated into engineered and non-engineered artifacts. That is, are all technical artifacts created by a process we might describe as engineering, or are some created by other means? This question obviously has bearing upon another question, namely, What is engineering? I will argue that engineered artifacts can be distinguished as a special case of technical artifacts. Exploration of this distinction centers upon the process by which a functional description gets converted into a physical description, which might generally be thought of as the design process. In particular, I will examine how specifications are defined and satisfied, and will propose that the role of specifications is central to the notion of engineering and to engineered artifacts. However, one result of this line of reasoning will be that the mapping between engineered artifacts and engineers is not necessarily one-to-one.

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One Engineering Account of Technical Functions

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Aim

To present an account of functions that incorporates and explains the co-existence of three archetypical concepts of function used in engineering design methodology.

Background

In my WPE 2007 contribution I argued that research on conceptual, methodological and epistemological issues is difficult to establish via direct engineering-philosophy collaboration. Both disciplines are too different to keep the collaboration running: engineering favours effectiveness and efficiency responses to issues, whereas philosophy allows for academic analyses that may unearth further problems. The illustration was research on technical functions, where engineering favours crisp and flexible definitions, and philosophy subtle and complicated analyses. The conclusion was a plea for making conceptual, methodological and epistemological research relevant to addressing ethical and political questions about engineering; the engineering ethics-community may provide a niche in which engineers and philosophers can collaborate more constructively (Vermaas, 2010).

Not being engaged in ethics myself, I ignored this plea, and continued doing research on functions, staying close to engineering practice and including the engineering aims of effectiveness and efficiency into the analysis. The task then becomes a paradoxical one of laying down the meaning of this term and explaining why engineers do not use it with one meaning.

Starting point

In engineering design methodology it is generally accepted that design researchers disagree about how to define function even though it is equally accepted that this disagreement leads to problems in the communication, storage and retrieval of functional descriptions (e.g., Erden, Komoto, Van Beek, D'Amelio, Echavarria & Tomiyama, 2008). In my paper I focus on three archetypical engineering meanings:

1. technical function as intended behaviour of artefacts,
2. technical functions as the desired effects of the behaviour of artefacts,
3. technical functions as the purposes for which artefacts are designed.

Rejecting the philosophical "disambiguation-is-progress"-response that these meanings should be replaced by one well-defined one, an account is required that brings a weaker form of conceptual unity, allows the three meanings to co-exist and explains that engineering benefits from this co-existence.

Arguments

First I argue that functions refer in engineering to states of affairs that artefacts, by their design, are supposed to realise when they are properly used. Function is in this way a concept useful in design reasoning. Designing starts with a goal to be achieved as formulated – in precise or less-precise terms – by an external party (the client). This goal is translated into the task of designing an artefact that can realise a state of affairs instrumental to achieving the client's goal, i.e., into the task of designing an artefact with a specific function. Finally an artefact is determined that can realise this function by its physical behaviour (e.g., Brown & Blessing, 2005).

Second I argue that the three archetypical meanings of function emerge as rational ways of giving content to this overall meaning of function: I review three design methodologies and show that the reasoning schemes these methodologies propose each single out a different archetypical meaning as the effective and efficient meaning of functions in design reasoning (Vermaas, 2009).

Third I argue that the second "desired effect" meaning can be considered as the overall meaning for which engineers use the term function: the first "intended behaviour" meaning refers to the desired effect by means of the full behaviour that is to realise that effect; the third "design purpose" meaning refers to that effect by means of designer intentions.

Results

The account provides an understanding of functions that brings unity, stays close to the way in which engineering use the term function, and explains this way. It also gives a basis for addressing the communication problem. Yet, it still needs to be understood why in engineering one key-term remains to be used with more than one meaning.

The account presented may again invite the "disambiguation-is-progress"-position. Yet arguing that the "desired effect" meaning is the only true meaning of function, or arguing that the archetypical meanings should be clearly set apart, would again create distance between the philosophical analysis and the actual engineering practice. The term function rather has three co-existing meanings in engineering, of which two may be taken as special cases of the third more general meaning.

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Argumentation as Engineering and Vice Versa

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Human ancestors left some of the earliest evidence of tool manufacture and usage in stone axes nearly 2.5 million years ago (mya). We don't know what was going through the minds of those early inventors and engineers, but recent work in how people really make decisions (Klein, 1998) can help make sense of those early acts and can help shed light on the historical and intellectual relationship between engineering and philosophy. In particular, the paper argues that the early engineering of primitive artifacts was a necessary and related precursor to the philosophical skill of argumentation. Once this relationship is put forward and supported, the paper turns the topic on its head and looks at argumentation theory as a way to be more explicit and integrative in thinking about a number of engineering acts. The remainder of this abstract considers these two distinct parts of the paper briefly, in turn.

The first part of the paper starts 2.5 mya with Homo habilis and the Oldowan tools, progresses to Homo ergaster, the Archeulean tools, and the control of fire ($\sim$1.8 mya), and continues to Neanderthals, Mousterian technology, and the first composite tools ($\sim$50 kya). Although we cannot directly know the mental life these early innovators lived, we can start with the mental life of a modern engineer and reflect on how many engineering innovations today are visual imaginings, oftentimes modifications of existing artifacts that come to engineers in the mind's eye (Ferguson, 1993). Studies of naturalistic decision making or NDM (Klein, 1998)—how high stakes decisions in the real world are actually made by such professionals as fire fighters, soldiers, and engineers—suggest that decisions in such settings are made by considering a single solution that comes to mind through a process of recognition primed decision (RPD) after which that single solution is quickly checked using a rapid, coarse process of mental simulation. The full paper discusses these models in some detail, but here the engineer's imaginings are seen as a form of NDM, and it is reasonable on evolutionary grounds to suggest that early artifacts were designed in similar fashion. Recognizing that early tools were the first complex, external concrete objects created by a human mind and shared with other humans, recognizing an argument as a complex shared conceptual object shared with other humans, and taking together the underlying natural reasoning capability of NDM in early and later humans, we conclude that philosophical argumentation may reasonably be viewed as a somewhat refined abstraction on the method and form of early engineering invention.

The second part of the paper takes some of the refined abstraction of philosophical argumentation to heart and considers it in light of engineering reasoning. Starting from an earlier discussion of the economy of engineering thought and a related spectrum of models (Goldberg, 2002), the paper seeks to integrate apparently disparate forms of engineering reasoning using Toulmin's model of argumentation (Toulmin, 1958). The paper presents Toulmin's theory as a relaxation of modus ponens, a relaxation that is equally at home in understanding informal causal chains describing artifact function and malfunction or in understanding scientifically or mathematically rigorous explanations of state variable evolution. An example drawn from an industrially sponsored senior design project at the University of Illinois—reduction of dusting flour in a tortilla manufacturing plant—is used to illustrate the argument. Moreover, the economic setting underlying engineering decision making is particularly important here, and the paper links Toulmin's formal structure to the economics of engineering thought, thereby helping to understand some of the resource tradeoffs engineers face in thinking about analysis and design.

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Orchestrators or Facilitators

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This paper questions whether or not the Engineering Profession's self-knowledge about its role has progressed since its early days, and it looks more closely at the meaning of that role itself.

Résumé

Engineering, in the sense we know it today, probably started around the time that rules of thumb techniques were abandoned and replaced by a more formal application of science in order to make and build things. Since then engineers as a profession have seen themselves as more than just craftsmen, and many in the UK even now still believe that they remain the unsung heroes amongst professionals. There certainly is a cycle of rising generations of engineers, each of which keeps trying to improve its standing in the public eye. Letters published today in Civil Engineering journals make exactly the same points as those written well over a hundred years ago.

That point aside, namely the perceived relative worth of various professions, (which probably has more to do with the mysteries of fashion and the fluctuating financial values of works of art, equities and other treasures) it is not really the same as asking whether the modern engineering profession is entitled to be seen as a vocation, namely whether it is one which has an absolute value in itself.

Is the engineering profession more than just a wide spectrum of those who do not quite fit anywhere else in any of the other occupations for which their analytical education might have been suited? They (engineers) are definitely not scientists on one hand, where it is more important to test a theory against practical result than it is to achieve a (good) practical result by whatever means are available at the time, without understanding it to the very limits. Engineering and philosophy too, are nothing without creativity, in that their principles are propounded and not discovered, as opposed to science and possibly mathematics. But are engineers still simply driven just to find what works to serve practical needs, or has a dedication to the strictures of mathematical science really taken over as its driving force, and indeed, is the powerful and simple motive of profit something that has been glossed over lately not only by the professional bodies, but also by academics? Despite the philosophical recognition of types 1 and 2 rigour, when it comes to applying theories, has the profession really moved from the days when it was openly advocated by its leaders that the art must precede the science?

Professional Rivalry

Architects and Engineers rail against each other, for example, when it comes to proposing the best conceptual designs for bridges. If a few years are available in which to raise funds and obtain permission for construction, this is fine, the professions may indeed jockey for position. Arguments will take place over which design is best, or the most practical. The difficulty is that a project of this type is indeed a piece of architecture or even planning, but it is inextricably linked and even depends upon fundamental engineering solutions, which themselves influence the concept, in order to put it into practice. However, it is very different in extreme cases, when for some reason an existing bridge collapses, and the two sides of the obstacle it spanned need to be re-connected urgently. An obvious engineering function is simply required, the concept of how this should be done is clearly the solution which can be achieved most practically. Debate is not required. The engineering question arises, namely, what is the simplest way of solving the problem. In this, and in other cases of emergency work like disaster relief or rescue work the engineers' role is clear. But even when it comes to rescue work, the engineer serves the rescuers, and should not direct them. In more complex practical cases the function of engineering is ambiguous and becomes intertwined with relationships with many other professions. Remedial or repair work remains a clear field of engineering, and is perhaps a pointer to its meaning.

Engineering Innovation

In the past, many grandiose definitions have been applied to Civil Engineering and until a few years ago it was still seen as the application of science to direct Nature for the use and convenience of Man. Some of these definitions have been re-written to suit the tone and style of today, but there is still an underlying assumption in them that it is engineers who are the guardians in some way of universal physical resources. Certainly, the physical foundations of civilization such as buildings, communications, water supply and drainage all rest upon engineering achievements. These things are the results of engineering, but engineers can do nothing without clients to commission and pay for them. Any engineering innovation has to be judged on many other grounds than simply, is it 'good'. First, it has to pay its way, in order to convince someone to construct or build it. Many of the prized works which are seen as engineering achievements are retrospective, and in fact arose out of the chaos of earlier successful innovations. Drains have to be provided for disease-ridden overcrowded cities, highway networks have to be devised to cater for an unexpected increase in the number of horseless carriages, airports have to be conceived to cater for heavier than air flight. Political agencies then have to be founded to control the unexpected effects of the earlier innovations, but they do not devise anything fundamental themselves. Although dealing with engineering artefacts, is this really engineering in an ingenious or creative sense that provides motivation. If the engineering profession were in some way to ever be entrusted with an overriding control of natural resources, in the first place it would be an impossible assignment, and it would also require a complete and unlikely shift of political philosophy.

Practicalities

The engineering profession may not easily be judged to be strong or weak, in a philosophical sense, because as an entity itself, it is amorphous, and also wide ranging. Professional engineering is perhaps unlike some other professions in that it is scattered seemingly at random within an industry of technology which encompasses engineering, rather than existing as a distinct and separate strand. The engineering profession also suffers from an unquantifiable difference between the qualities required of technicians and of engineers. The fundamental essence of engineering, as opposed to the mastery of technology by technicians, is liable to always remain elusive, as it is so interwoven with the physical advancement of technology.

Some of the elusive quality of a 'great engineering' project lies in the individual solutions of myriad problems in its many component parts, which may be in many branches of engineering, for example, structural, hydraulic, electrical and mechanical. Their summation, in order to bring them together on a large scale, may be something quite different to the job of finding the individual solutions.

The question remains, though, should engineering be content to facilitate, or does it really have a duty to orchestrate?

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Engineering: a Micro-Meso-Macro Framework

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About twenty years ago, Steven L. Goldman wrote two excellent articles on philosophy of engineering. He said that philosophy of science, at that time, was a fully accepted and highly respected branch of philosophy while philosophy of engineering carried as much professional distinction as philosophy of parepsychology. However Goldman took an optimistic view of the future of philosophy of engineering. He held that philosophy of engineering should be the paradigm for philosophy of science, rather than the reverse.

At the beginning of 21st century philosophy of engineering becomes a new branch of philosophy. On the ground that some fundamental issues that challenge traditional methodology, epistemology and metaphysics have been raises in the field of philosophy of engineering, I support Goldman's view on the future of philosophy of engineering.

Engineering is an extremely complex phenomenon. For one thing, we should study engineering from different point of view, for example, philosophical, economic, sociological, managerial, institutional and psychological point of view; for another, we should study engineering on three levels, namely, microlevel, mesolevel and macrolevel.

Usually engineering is studied as a micro object. Now we should shift our attention from engineering as a micro object to engineering as a micro-meso-macro obeject.

The micro-meso-macro framework of engineering being a starting point, we can propound some new philosophical viewpoints.

First, we can find a new solution for the problem on the differences of opinions between methodological individualism and methodological holism by way of analyzing engineering as a kind of meso unit in the micro-meso-macro framework.

Second, in the field of theory of knowledge, it is not justification but creating, sharing, learning, organizing and managing of knowledge that comes into the limelight.

Last but not the least, from the linguistic point of view, it is not "I", "you", "he" and "she", but "we", "you" and "they" become subjects. In an engineering community individuals become members of the community. From the methodological and ontological point of view, an independent individual and the same people as a member of the community are both identical and separative.

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The Everyday Commitment to Sustainability: Thinking about the Culture of Consumption

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Technology, the productive skill which plays as a central element of John Dewey's instrumentalist philosophy, now is exhibited as a dramatic driving force of life world. The co-shaping theory of STS presents the dynamic socio-technical network that makes people believe technologies have been parts of human lives. From the psychological perspective, the consumers' behaviors have certain impacts on the technological markets through different preferences and other social dynamics, further, the developmental trajectories of technologies. A classical case is Wiebe E. Bijker's analysis "of bicycle". In everyday sense, people are so convenient to consume technologies that they have not been aware of the phenomenological existences of technologies through the productive activities (or the culture of consumption behind the physical existences of technologies) not to mention energies, materials, and natural resources which are more far away from the everyday experiences.

Divorce between Knowledge and Action in Sustainable Politics

The problem of ineffectiveness in sustainable politics today is the divorce between knowledge and action. One example is the divorce between lay citizens' awareness of the urgencies for sustainable development and their unawareness of the unsustainably everyday actions in the culture of consumption. At this point, this part will compare the different cultures of consumption between China and the U.S., especially for the public attitudes in the two countries to have vehicles. For instance, Americans like to buy trucks as a free and comfortable way of life, while in developing countries like China people have cars as the symbols for wealthy class. In this sense, both of them are not well conducting the sustainable development in having transportation means, though the urgencies of sustainable development is well known for them. From the Marxist theory, the preferences to have vehicles have been alienated by the culture of consumerism.

The liberal economist may argue that the individuals have the free will to choose their own ways of living including the consumption preferences. However, sociological studies of technology have demonstrated that products have been scripted into instrumental values by designers and corporations intentionally or unintentionally in modern culture of consumption. Products and simultaneous market technologies (e.g. advertisements) mediate (or shape) the perceptions and behaviors of consumers, and hence consumers are not totally free-will agents any more in the socio-technical hybrid network. Here is another way to interpret the consumers' divorce between knowledge and action, that is, consumers do not have the reflective knowledge or capacities to frame and analyze their actions in the commercial markets in order to pursue the de facto freedom, with the freedom that well purse sustainability by means of technologies.

Responsible Innovation to Fill the Divorce: Take Consumers into Account

Based on the analyses above, this part suggests that responsible innovation in designing, manufacturing, and marketing products should take consumers' mediation mechanisms into account. This approach expands and differentiates from the traditional marketing theories.

Such a kind consumer-centered culture of consumption refers two levels of responsible innovation: (1) companies are encouraged to innovate products integrate sustainable values (see Peter-Paul Verbeek's instance Eternally Yours that prolongs the psychological lives of products) that could shape consumers' perceptions and behaviors to be sustainable (Verbeek, 2006); and (2) with the social reforms such as the public discourses among different social groups, including companies, regulating agencies, governments, and consumers, the society will formulate an atmosphere which improves consumers' reflective knowledge or capacities to rethink the current culture of consumption and make reasonable choices. The two senses of responsible innovation help to fill the consumers' divorce between knowledge and action and cultivate them to be junzi (superior person in Confucian doctrines) — people with the virtues (e.g. cheng) that unite the knowledge and action in Chinese philosophy.

A Plea for Everyday Ethics of Technology

At the methodological level, this part reflects the research approaches in ethics and technology studies and calls for an everyday ethics of technology that contextualize the ethical critiques on technology in the culture of consumption by practicing day-to-day reflections in the life world. According to the linear policy model, the two main approaches are top-down (policy regulation) and bottom-up (public participation). Everyday ethics of technology will be valuable for both of the two approaches to describe the social needs and improve the public participatory capacities. As Mike Martin notes, the moral aspects of day-to-day living are "more direct, persistent, and urgent" than the global moral issues. (Martin, 1995) Additionally, from Paul T. Durbin's progressive activist approach, this everyday ethics of technology will also help to practice the experimental learning in society, solve socio-technical problems piecemeal, and amend the technological culture.

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Analysis of Student Service-Learning Reflections for the Assessment of Soft-Skill Development

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As part of a National Science Foundation Department Level Reform (DLR) grant, the civil and environmental engineering (CEE) programs at the University of Vermont (UVM) incorporated systems thinking and a systems approach to sustainable engineering problem solving. A systems approach means incorporating long-term social, environmental and economic factors within the context of the engineering problem solution and thus encompasses sustainable engineering solutions. Our goal was to prepare students to become leaders in their chosen field who could think long-term and anticipate co-products associated with forecasted solutions. As a way of practicing the systems approach, we have incorporated service-learning projects in many of our courses within the undergraduate engineering curricula, culminating with the senior capstone design course. We have used a variety of formative and summative assessment methods to gage student understanding and attitudes including student surveys, focus groups, and assessment of student projects in addition to student reflections.

Student reflections from two courses –Modeling Environmental and Transportation Systems (31 juniors) and Senior Design Project (30 seniors) are compared. Of these, 25 students were common to both courses. The focus of the systems modeling course project involved the mentoring of a home-schooled children (11–14 yrs old) to solve real engineering problems of mobility, while using the fun/inspiration of biomimicry. Students were required to invent innovative methods to move people, goods, etc. that improve associated constraints (i.e., amount of congestion, pollution, safety hazards), or reduce the need for transportation altogether. The project was worth 25% of the course grade. The capstone design involved a comprehensive design project involving two or more of CEE sub-disciplines accounting for the entire course grade. These service-learning projects were intended to enhance students' academic learning experience, attain civic engagement and reinforce their transferable skills (written and oral communication, teamwork, leadership and mentoring skills). The student reflections in these courses were not guided, yet they provided interesting data to assess commonalities and differences in student attitudes toward their service-learning projects, and specifically, development of soft skills.

In the spirit of service-learning pedagogy, we divided the contents of students' written reflections into three categories – academic enhancement, civic engagement and personal growth skills. The commonalities focused mostly on the civic engagement. Differences were observed primarily in academic enhancement and personal growth categories. The students reflected more on the personal growth aspects (e.g. leadership skills, mentoring, creativity, organizational skills, communication to nontechnical audience) with respect to the biomimicry design projects. Whereas, the senior design reflections concentrated more on the academic aspects, specifically, technical content of the projects.

It appeared that the students considered and appreciated the enhancement of technical skills as a part of their engineering experience in senior design. However, although significant discussion on personal growth appeared in the biomimicry-related reflections, it was not necessarily appreciated by the students as “real” engineering.

Engineering as an Enterprise of War and Peace: Further Reflections

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Engineering profession and practice, as well as technology in general, owe much of their evolution and development to sponsorship from military agencies and/or development of military and defense technologies. A careful examination of research funding and employment statistics demonstrates that these strong ties persist today (Papadopoulos & Hable, 2008). The prevalence of military and defense applications as drivers of engineering and technology raise a host of ethical and social questions. Although previous (Mitcham & Siekevitz, 1989) and more recent (Riley, 2008) scholarly attention has been paid to these matters, a survey of published educational materials indicates that they are insufficiently addressed in engineering education, including engineering ethics education (Papadopoulos & Hable, 2008). Based on this empirical evidence, we argue that engineering students are likely to encounter questions of military and defense work in their professional or academic careers, and correspondingly that engineering education must engage students in critical thinking and reflection about the many issues that arise from the military and defense underpinnings engineering.

More broadly, Papadopoulos & Hable (2009) further examine the social implications of a preponderant military and defense influence in engineering and technology. Citing the framework of Homer-Dixon's (2006) five "tectonic stresses" that threaten to disrupt world socio-political order in the coming decades, we question whether continued dominance of military and defense interests in engineering will promote peace and justice. In this context of diminishing resources and corresponding increased competition, we raise the two-fold concern that emphasis of military and defense applications provides systems and hardware that directly fuel conflict, and at the same time diverts essential expert attention away from addressing crucial social needs (such as reducing extreme poverty) that could diffuse conflict in the first place.

For these and other reasons, we argue that engineering research and practice must newly prioritize humanitarian and peaceful objectives. While recent decades have attracted many engineers to volunteer for such activities, emerging interest in humanitarian engineering (Lucena et al., 2010) and appropriate technology will provide new academic and professional opportunities for engineers who desire to devote their principal energies toward addressing critical (and neglected) human needs. Such opportunities will also serve engineers who seek to avoid military or defense work due to moral convictions, although professional military service personnel also have important roles to play in serving humanitarian causes (within carefully observed limits of exercising military power). Without the institutionalized attention and commitment of the best and brightest engineers, the pressing causes of the next decades – eradication of extreme poverty, general access to clean water and energy, and decommissioning of weapons of mass destruction, to name a few – are unlikely to be met.

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Engineering as Performance: An “Experiential Gestalt” for Understanding Engineering

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Engineering practice has long been a topic of interest. More recently, some of that interest is focused on attempting to cull what is essential to engineering and engineering beliefs, values, and knowledge. The motivation seems to be that a better understanding of the nature of engineering will suggest better approaches to teaching engineering – problem-based/project-centered learning (Sheppard et al., 2009) or “the CDIO approach” (Crawley et al., 2007). Also, there is a general consensus that society needs more engineers. A report by the National Academy of Engineering suggests that the general public and in particular young people “have a poor understanding of what engineers do” (Committee on Public Understanding of Engineering Messages, 2008). Consequently, if the engineering community could “reposition” engineering practice as a way to “make a difference in the world;” then perhaps more young people would be attracted “to pursue engineering education in the future” (p. 10). Finally, there are a growing number of qualitative/ethnographic-like studies that investigate real world engineering practice. In this regard, James Trevelyan is doing some very interesting research using interviews and field observations (Trevelyan, 2007, 2009). Based on that research, he offers an alternative understanding of engineering practice as “technical coordination” (Trevelyan 2007). Trevelyan rightfully claims that such an understanding facilitates the important recognition that “engineering is [both] a technical and a social discipline . . . [and that] the social and technical are inextricably intertwined” (Trevelyan, 2009).

Much that is positive has stemmed from this interest in engineering practice. Engineering educators have made substantial progress in providing students with good and useful and powerful learning experiences and a foundational understanding of what engineering educators want them to be able to do. Also, thoughtful “messaging efforts” at least have the potential to improve general “technological literacy,” a very important aim in our “technology-dependent society” (Committee on Public Understanding of Engineering Messages, 2008). And, perhaps one of the most positive results of the qualitative research of engineering practice has been the rejection of long-standing false dichotomies – theoretical versus practical knowledge, hard versus soft skills – in addition to warning of new (or re-emerging) false dichotomies – academy versus workplace.

However, while the concept of practice allows us to explore engineering as an ever varied and variable collection of actions relevant to purpose, this same heterogeneous nature resists both a simple and elegant theoretical formulation and the necessary integration of new knowledge in ways that allow for coherence. Consequently, given the diversity of practices that are possible in engineering, there is a growing discussion, perhaps even confusion about what engineering really is. Performance does offer such a formulation along with an opportunity for coherence.

Performance is an “essentially contested concept” that has emerged, very eclectically, from a broad range of disciplines/fields – sociology, anthropology, linguistics, literary and rhetorical studies, theater and/or performance studies, even philosophy (Carlson, 1996). Still, in referencing these various disciplines/fields, there is an agreement that performance is doing; it is redoing; and it is showing doing (Schechner, 2002). To say that performance is doing emphasizes the importance of acting. To say that performance is redoing suggests that performers who act never do so apart from tradition and/or convention. And, to say that performance is showing doing highlights performers' awareness, most importantly, of themselves as distinctive agents. I begin my paper with a brief overview of performance.

Then, since my particular interest is language use in engineering, I discuss the ways that performance helps us to better understand communicative practice(s). Communication, like other types of engineering practice, is an ever varied and variable collection of situated and recurring actions relevant to purpose. We term these actions genres (Bazerman, 1999). And, like other types of engineering practice, communication in engineering is informed by tradition and/or conventions. It is important that students access that tradition and those conventions because that access not only provides scaffolding for their participation in the community of engineers, but also, through performing those genres, they develop genre knowledge or an understanding how to act communicatively (Berkenkotter and Huckin, 1995). And again, like other kinds of engineering practice, performing those genres and displaying genre knowledge, at least in part constructs and represents their awareness of themselves as agents, their emerging identity as engineers (Butler, 1990).

Finally, and again briefly, I suggest that the concept performance represents an "experiential gestalt," or "a structured whole within our experience" that allows us to explore the various constructions of engineering mentioned above (as well as others) in terms of doing, re-doing, and showing doing (Lakoff and Johnson, 1980). Discovering the ways in which these constructions correspond or not to one another enables us to see coherence across the varied and variable practices that are engineering and to develop a more complex, less disjointed understanding of what engineering really is.

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Using Games to Teach Sustainability Ethics

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When ethics is formally introduced in graduate science and engineering curricula, it is typically through an individualistic, professional ethics approach that supplements indoctrination to rules of conduct with case study readings about the catastrophic consequences of ethical “failures.” Although these case studies are often abstracted from real events, they fall short of cultivating an emotional resonance among students with limited real world experience, and give the misleading impression that impropriety occurs only when “bad apples” act without due regard for others. Consequently, science and engineering students often feel disconnected from a traditional ethics pedagogy, which typically lacks the active, experimental and collaborative learning exercises that have been proven effective in other science & engineering subject areas. This is particularly problematic for questions of sustainability that demand a greater level of complexity and broader scope than professional ethics.

Incorporation of sustainable development into the fundamental ethical canons of engineering has presented at least two serious challenges to science and engineering educators: The first challenge is that sustainability is not reducible to a tractable definition that is amenable to traditional problem-solving strategies. Indeed, sustainability remains an essentially contested concept. It engenders passionate and seemingly interminable normative disagreement as the following questions keep getting raised. Sustain what? Sustain how? Sustain for how long? Sustain for whom? In light of the regularity in which these questions appear, sustainability is characterized as a wicked problem: no definitive formulation exists; no technical algorithm can provide the single best solution; the combination of high stakes and dangerous externalities allows for very little error to be tolerated; and, no uncontroversial stopping rule can be appealed to.

The second challenge is that there is a paucity of exemplary course modules and/or case studies that illustrate how to put the principles of sustainability as an ethical concept into practice. Consequently, educators and practitioners alike are forced to confront complex ethical issues practically unaided.

In this presentation, I will discuss a current NSF funded initiative that is taking place at Rochester Institute of Technology and the Arizona State University. That initiative is a collaborative arrangement with two philosophers and a civil engineer as principal investigators, and a faculty member and undergraduate student from RIT’s Interactive Games and Media Department as supporting researchers. We are in the process of creating a game-based approach to teaching sustainability ethics that features modules in the following core topics: externalities, Tragedy of the Commons, inter- and intra-generational justice; and weak vs. strong sustainability. Our hypothesis is that mathematically simple games underwritten by game theoretic assumptions will improve upon current pedagogical practice by creating emotionally and cognitively resonant experiences that draw upon engineering and science students’ predilection for experimentation. The anticipated result is that students will acquire significant deliberative skills and a newfound respect for the norms of discourse ethics. Our long-term goal is to use information communication technology to extend our proposed ethics laboratory to a global scale, such that students from different countries can learn about and from each other through synchronized game-play that emphasizes rather than diminishes cultural differences.

In pursuing such a grand plan, we have encountered both practical difficulties and a range of theoretical objections. The main aim of this talk is to facilitate a critical conversation with the audience about the project and the emergent difficulties/objections. Ideally, two goals will result: 1) our initiative, which is at its early stage of development, can be improved; and, 2) audience members who are interested in enhancing engineering ethics and sustainability ethics education can come away with new innovative ideas to incorporate into their own projects.

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Teaching Ethics to Engineers—Bringing Academic Staff on Board

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Knowledge of professional ethics and the capacity for ethical reasoning are now common requirements for professional accreditation of engineering degree programmes. Integrating these requirements into an already overcrowded curriculum presents a significant challenge for engineering schools. The capacity of engineering academics to engage with ethics at a sufficient level in order to teach ethical principles and guide students in developing skills in ethical reasoning may be limited. This paper presents the preliminary results of an evaluation of an initiative to integrate ethics into undergraduate programmes in civil and environmental engineering at UCL. It focuses on academic staff perspectives on engineering ethics and how to best teach ethics to undergraduates.

In 2006 UCL implemented a radical restructuring of its undergraduate degrees in civil and environmental engineering, presenting new opportunities to enhance student learning of ethics and wider contextual issues involved in engineering practice. The new curriculum is a hybrid of conventional lecture and laboratory learning and problem-based learning. The most radical changes to the programmes have occurred in the first two years. The first and second year curriculum is divided into four clusters – tools, mechanisms, context and change – which are taught in four week blocks of lecture and laboratory classes each followed by one week intensive group projects called scenarios. The tools cluster includes mathematics, computing and communication skills. The mechanisms cluster covers essential civil and environmental engineering sciences. The context cluster addresses sustainable development, professional practice, public engagement, history, economics, statistics and geology. The change cluster includes design exercises, systems engineering and the week-long scenarios. Students complete 8 scenarios in their first two years.

Whilst the scenarios and context cluster improved student learning about the role of stakeholders, sustainable development, professional skills and other non-technical engineering concerns, learning outcomes related specifically to engineering ethics remained limited. In 2009 we developed a detailed plan for integrating ethics learning outcomes into the new curriculum, based on the Royal Academy of Engineering ethics curriculum map. A range of learning resources and activities were collated to help staff deliver ethics teaching through new and existing lectures, scenarios, tutorials and assessment.

The ethics initiative has been led by staff with particular interests in the philosophy and ethics of engineering. However, the implementation of plan for ethics requires contribution from most academic staff in the department, many of whom have limited interest or prior knowledge of engineering ethics. This presents the outcomes of a series of interview with academic staff who will be required to integrate engineering ethics into some element of their teaching in order to achieve the learning outcomes proposed in the UCL ethics curriculum plan. The interviews address academics personal ethical frameworks as well as their opinions and experiences of teaching ethics to undergraduate students.

Malintent: a (Mis) Application of Neuroengineering to Homeland Security

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Neuroscience and the behavioral sciences are yielding new technologies that use physiological data to infer intentions, truth-telling, personal preferences or other facts about an individual. These technologies are approaching the point of moving out of the laboratory into use in socially important applications.

In this talk I consider the possible use of remote monitoring of physiological data from individuals to detect intent to cause harm or commit crimes. One example is the Future Attribute Screening Technology (FAST) Project, a program under the support of the (U.S.) Department of Homeland Security Agency intended for airport screening applications. Another example is a "pre-crime" detector that at least one company offers that monitors employees' heartbeats as an indication of possible criminal intent.

So far the technical characteristics and performance of the FAST system have not been described in peer-reviewed literature, but results of preliminary tests and promotional materials from the developers are available in various media reports. Preliminary tests are claimed to show that the system has an 80% accuracy in identifying individuals with "malintent" in mock scenarios.

These technologies raise a number of potential practical and ethical issues. Despite hyperbolic claims by its developers, simple calculations based on Bayes' theorem show that the FAST system will be utterly incapable of detecting with any reliability individuals in screening situations with "malintent", a consequence of the low base rate of such individuals in ordinary screening situations – a problem that also exists with new neuroscience-based approaches to truth testing (Wolpe et al 2005). In real-world use, FAST would most likely be a form of what one security expert calls "security theatre", elaborate measures that give the appearance of increasing security in airports but in fact do not. As with polygraphy, systems such as FAST and "pre-crime" detectors are likely to be susceptible to abuses, in which authorities can use their ostensibly scientific nature to manipulate individuals into false confessions. Finally, as physiological monitors, such systems are capable of producing incidental findings of potential clinical significance, raising questions about the responsibility of disclosing such information to the individuals being screened.

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Robots and Ethical Responsibility

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Robots are becoming more and more prominent in our technological society, including military robots, robot vehicles, industrial robots, space robots, personal robots, service robots, and robots for biomedical applications. Robotic applications that are either commercially available or the subject of significant ongoing research include pets, toys, vacuum cleaners, lawn mowers, armed security guards, armed border sentries, construction and factory workers, maids, home monitors ("tele-presence robots"), companions for children, caretakers for the elderly and infirm, museum tour guides, and combat troops. There are currently more than 4,000 military robots deployed on the ground in Iraq (as well as unmanned aircraft). One observer has noted: "A robot does what it's told, and you'll be able to get them to advance in ways it's hard to get human soldiers to do. They don't have fear, and they kill without compunction." (Pasulka, 2008)

Along with developments in robot technology, scientists, technologists, and ethicists are beginning to develop an ethics of robots. South Korea and Japan have already begun work on codes of ethics for the development of robots, both for the protection of humans and the protection of robots. Professional groups have begun to form around ethical issues, such as the IEEE Technical Committee on Roboethics, and other groups such as the European Robotics Network (Euron) have begun engaging in ethics and legislative activities.

Robots pose a number of ethical problems relating to such concepts as moral agency, free will, human identity, social roles, and potential marginalization of humans. Issues include consumer safety, product liability, and whether robots should/will ultimately have rights (as in the current case of debates over animal rights). Robots used in military roles raise a number of ethical questions, such as the predictability and control of the robot's behavior regarding desirable and undesirable consequences. Perhaps trumping all of these concerns is the question of whether robots can (and should) become autonomous beings capable of making ethical decisions.

Arkin has proposed that military robots could be programmed to follow the conventions of war: "My research hypothesis is that intelligent robots can behave more ethically in the battlefield than humans currently can." (Dean, 2008) Other technologists have gone further, claiming that intelligent machines may someday transcend not only human intelligence as we know it but also human moral character. (Hall, 2007)

In this paper we will examine robots from the point of view of professional ethics, with particular emphasis on the ethical responsibilities of engineers and computer scientists. Among the questions considered will be: 1) What are the ethical responsibilities of engineers and computer scientists engaged in the development of robots that will be programmed to "make decisions" that have ethically significant consequences? 2) Will (or should) robots come to be regarded, to some degree at least, as "autonomous moral agents?" (Wallach and Allen, 2009) If so, what are the ethical responsibilities of engineers and computer scientists engaged in the development of such robots?

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Warfare Through Robotic Eyes

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Telerobotic and semiautonomous weapons systems are a reality on the battlefields of today. Unmanned weapons such as the Predator and Raptor Drones have been the product of concentrated levels of defense spending and research. In other works I have written much about the ethical concerns of deploying such machines (Sullins; forthcoming, 2010, 2009); but here I would like to focus on the epistemological concerns that are raised through the engineering choices made in the construction of these systems.

The primary questions under consideration are: how do these systems change the way armed conflict is seen and understood? How do these systems influence the way human agents who use them see the battlefield? Conversely, how are they seen by the human agents who may be targets or witnesses of the military actions propagated by these technologies? These machines serve as both an epistemic lens thorough which modern warfighters see the world and also as a persona that is presented to the world that sends a certain message about the civilization from which it was deployed.

Here I am not focusing on autonomous weapons as an object of knowledge but rather as an object that produces knowledge. Undoubtedly, the construction of an autonomous weapons systems require modes of knowing that are philosophically interesting in there own right. The machine, as an object of knowing, causes us to ask all the standard philosophy of engineering questions such as those outlined by Carl Mitchm (1994), in this instance they would include; design concepts, specifications and measurements, theoretical constraints on the design, the processes and instruments used in the design, the automation of flight and deskilling of the pilot, etc. But what I want to focus on here concerns technology as a mode of knowledge-production from both the angle of the warfighters using the technology and the point of view of the victims and bystanders.

The whole point of designing autonomous and semiautonomous weapons systems is to remove human warfighters from the locus of hostilities. The benefits of doing this are obvious, but once this is achieved, the machine becomes the filter through which information about the combat situation is delivered to the operators and their commanders, who may be many miles away from the front lines. This means that the battlefield situations, and those remaining humans left on it, are seen mediated through the telerobot. Following the roboticists Ken Goldberg, I will refer to these situations as telepistemological (Goldberg, 1995, 2000). Although the philosophical concerns about technology and epistemology are as old as when Galileo attempted to convince his detractors that his telescope was giving him true knowledge of the heavens, I hope to add weight to the idea that there is a new and more interesting wrinkle provided by robot telepistemology, one that is already changing the way we make life and death decisions on the battlefield.

There are two locations for potential telepistemological noise in the robotic weapons systems we design. One is found in the technological medium the data is transmitted through and the other is the found in the operator's training and preconceived notions about the data as it is presented by the system.

The first type occurs because the operators of telerobots see the world differently while controlling the machine. This impacts the decisions the operator is making in directing the operations of the robot. When one is experiencing the world through the sensors on a robot, one is experiencing the world telepistemologicaly, meaning that they are building beliefs about the situation that the robot is in even thought he operator may be many miles away from the telerobot. This adds a new wrinkle to traditional epistemological questions. In short, the sensors on the machine (and the systems back where the pilot is controlling the machine) process the information and then present it to the operator thus mediating the operator's beliefs about the world (Sullins 2009).

While we may think that these machines see the world with precision, the truth is that there are certain difficulties. The machines send back a great deal of data, but that data takes time to understand and synthesize, and time is a luxury on the battlefield. This necessitates making decisions that may be rushed and based on an incomplete understanding of the situation at hand (Singer, 2009).

Technologies are fundamentally shaped by the values held by their designers and contribute to a lifeworld that reflects and justifies these same values. This process is easily seen in how industrial technologies were built with production and efficiency in mind. This has created a world in which it is difficult to see any alternatives to high production and extreme efficiency. Robotics, of course, has grown out of industrial technologies and shares these values, but it is also taking on the values necessitated by military technologies.

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Engineer's Nescience and How He Knows It

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Introduction

Vincenti (1990) analyses problem solving in engineering design as an epistemological problem. But all problem solving starts from ignorance as a lack of knowledge; R&D departments communicate their ignorance of certain topics; creativity is unpredictable, thus being a case of ignorance; and unknown possible consequences of technology, i.e. of ignorance, are evaluated by TA. Therefore we need a step back and look at ignorance designating technological problems. Ignorance is a new point of interest (Smithson 1989; 1990; 2008; Proctor & Schiebinger (2008); Banse e.a. (2005); Gamm e.a. (2005)); but the engineer's ignorance has been neglected, since the discussion has been dominated by the use of the concept as kinds of knowledge suppression or manipulation instead of missing knowledge. As an epistemological problem (sketched by Tuana (2008)), it means asking for the conditions according to which we can conclude from ignorance, which problem has to be solved.

Knowledge and ignorance

This presupposes dealing first with knowledge and ignorance (as non-knowledge). Types of knowledge an engineer relies on include Know that as fact knowledge, Know why as theoretical and causal knowledge, Know how as practical action knowledge, and Know wherefore as normative value knowledge. But corresponding forms of ignorance cannot consist in unawareness, nescience, disability and blindness – an engineer's ignorance has a typical character: It is a knowledge of non-knowledge (meta-knowledge), has a content, leads to a problem, and can be formulated as a question. Therefore, an engineer's ignorance has a structure and a content.

Ignorance as knowledge of knowledge limits

Kinds of Ignorabimus to be respected by engineers: (i) The impossibility to axiomatise technology completely – Gödel's result excludes a universal PC-program for an Ars inveniendi. (ii) The impossibility of a perpetual mobile – we need energy. (iii) The impossibility to enter the uncertainty relation or to leave our light cone – important for nanotechnology and signal transmission. (iv) There is no forecast in complex systems – predictions in feasibility studies presuppose a complexity reduction lacking reliability criteria.

Ignorance as a problem to be solved

An Engineer's ignorance means: There is a problem to be solved. Or: There is an aim to be reached. Therefore, the engineer needs knowledge concerning means for an aim as a functional compliance, how to gain and to use such means, concerning values behind the aim, and how to modify the aim in the light of values, if necessary. -

Epistemological remarks:

(i) Means, ends, functions are not observable – they are teleological interpretations.

(ii) An artefact is materialized knowledge and instantiation of values – which demands a hermeneutic interpretation.

(iii) Ignorance as a problem fixes the direction of the aim, not a specific end.

Therefore the knowledge that one requires precisely these kinds of knowledge is part of the ignorance structure and constitutes its content.

Three areas of ignorance in engineering

1. Classical civil engineering: If ignorance leads to questions, for which problem solving methods exist, it is resolvable step by step in a sequence of minor ignorance problems with sub-questions and sub-aims (Ropohl 2009: 262). In cases of nanotechnology, basic knowledge is missing; one needs further research, or its commercial use will remain ignorant of risks and dangers: This requires ignorance management (Smithson 2008: 214f). If a solution method is missing, creativity is demanded – a hard case of ignorance, since the solution is not predictable. But even there, the ignorance-problem and -question are the guideline. -

2. Biotechnology: Biofacts (living artefacts) grow and are autopoietic systems interacting with the environment – which excludes predictions: This is a very new ignorance type. - 3. Information technology: Information is neither matter nor knowledge; its manipulation by machines leads back to ignorance concerning the mind-body-problem. IT transforms society; but we are ignorant concerning the outcome. IT means power; but we are ignorant concerning a balance of power. So, we meet new types of ignorance, too. -

Thus, the new technologies lead to new forms of ignorance, where the old approach taking ignorance as completely structured by the corresponding problem and question is not sufficient.

The extension of ignorance by value problems

Throughout planning and developing, the engineer has to include the whole area of technological, economic, social and environmental values and their tension (VDI Guideline, 2000). Consequently contents and structure of the engineer's ignorance are extended by including values as a part of the problem constitution. This holds for feasibility studies – but since they depend on complexity reduction, ignorance is not eliminated, because reliability criteria are missing. Therefore, the knowledge of our ignorance is an essential challenge for engineers, philosophers, and probably for the survival of humankind.

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Stories of Engineering: Narrative Perspectives of New Engineers

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As new engineers confront the intractable realm of the social world, this experience is often problematic. An important source of the problem stems from the conflict between an educational logic based on scientific and mathematical prowess and the social logic within which engineering is embedded in practice (Buccareli, 1994; Pool, 1997). Interviews with newly minted engineers indicated that many struggled to adapt to a world running on a different logic than the logic of engineering as they were taught (Korte, 2009). The messier and more complex organizational environment (Schon, 1983) in which engineers began their career required a different understanding. This paper presents the narratives that new engineering graduates reported they formulated to make sense of and adapt to the world of engineering practice.

By narrating their experiences new engineers transformed a relatively disorganized set of experiences into a more meaningful and coherent series of events (Abell, 2004, Ochs & Capps, 1996). This paper uses a narrative perspective for analyzing the stories or experiences new engineers reported as they transitioned into the workplace. The analysis views engineering experiences as narratives comprised of individual, temporal, as well as technical elements. The views of these new engineers portray engineering as a dynamic process comprised of actors, actions, and relationships unfolding and evolving over time.

Some theorists stated that the world appears to people and is interpreted and understood by them as a narrative (Abell, 2004; Ochs & Capps, 1996; Searle, 1995). Thus for engineers and their work, an informative analysis might be found by perceiving engineering as a narrative that is often interpreted and understood in the form of a story. As such, the narrative becomes a useful tool encompassing a broader scope of the institutional or social world in which engineers work. Abell (2004) and others supported narrative as a means of sense making (Ochs & Capps, 1996; Polkinghorne, 1988). The factors comprising a narrative are:

1. A bounded set of system states including an outcome (bounded by the author of the narrative).
2. A chronology ordering the system states.
3. A finite set of actors (individuals or collectives).
4. A set of relationships between system states.
5. A set of actions that link/transform events from one state to another.

The narratives reported by new engineers in this study initially bounded their experiences primarily within the technical realm of work, grounded in the sciences and a systematic way of thinking about problem solving. Gradually this boundary expanded to include the social dynamics among the set of actors with whom they interacted in their work groups. Organizational, industrial, and societal factors also appeared in their stories as they expanded and redefined what it meant to them to be an engineer. Thus, engineering became a more complex and more socially derived profession for these recent graduates.

Narrative ways of explaining and understanding phenomena are not without controversy in the social sciences. Many of the problems turn on some of the philosophical debates in the social sciences between post-positivist and interpretive paradigms (Abell, 2004; Polkinghorne, 1988; Rosenberg, 2008; Searle, 1995). The controversy abates somewhat by adopting a hybrid view of social reality described by Searle (1995) and other social constructionists as a mix of institutional facts and brute facts. This combination of brute facts (those that exist independently of human interpretation) and institutional facts (those requiring human agency for their existence) compose our reality and affect how new engineers perceive and consequently make sense of their profession.

This paper draws upon the stories reported by nearly 80 new engineers in four large organizations to examine how newly graduated engineers narrate their transitions into the workplace. Their stories described their views of engineering work in large organizational settings, as well as the process through which they made sense of their experiences. Using a narrative perspective of work for understanding engineers and engineering in organizations might help deepen our understanding of the way engineering exists and unfolds in the workplace. Furthermore, it might help inform and update the institutional definitions and perceptions of engineering.

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What's Good for the Engineering Goose is Good for the Philosophical Gander

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As an engineer trying to become more familiar with philosophy, one of the more useful books I read early in my philosophical education was the late Jay Rosenberg's The Practice of Philosophy: Handbook for Beginners (1995), and I remember from that text that one of the more effective forms of attacking an argument is using the argument itself against its proponent.. The ways of doing this are quite various (Bartlett, 1988), but the point here isn't to examine the modes of petard hoisting exhaustively. Instead, this paper considers both common and particular arguments made by philosophers about engineers, engineering, and technology with an eye to seeing how those arguments hold up once they've been turned around and applied to philosophers, philosophy, and widely held arguments. The full paper examines three case studies: (1) ethical urgings by philosophers for engineers, generally, (2) a definition of engineering (Davis, 1998) that relies on advanced human institutions, and (3) a taxonomy for the study of philosophy of technology that leads to priority for the positions held by philosophers (Mitcham, 1994). The abstract briefly discusses the methodology used, briefly outlines the first of the three arguments detailed in the full paper, and concludes by recommending the procedure of this paper as a way of checking philosophy/engineering cross-disciplinary arguments prior to publication and cross-disciplinary publications, more generally.

The approach of the paper is to consider an argument made about engineers, engineering, or technology, abstract that argument to its essential structure along a number of key dimension, and then consider whether that argument or a closely related argument holds when the critic-kibitzer becomes criticized-kibitzed. Although this approach isn't exactly the categorical imperative, it might help enforce a certain kind of consistency when one discipline takes on another; it should help guard against what we might term cross-disciplinary hypocrisy. Perhaps not unsurprisingly, many arguments that sound perfectly plausible when applied to "those engineers" sound considerably less strong when applied to "us philosophers." Not all of them self-destruct, but many of them need to be adjusted or reconsidered in the light of such turnabout-is-fair-play.

An interesting field to start our search for inconsistency is in engineering ethics. There are many papers that criticize engineers and technologists for their moral failings or ask engineers to mend their ways and be more careful about the consequences of the technology they set loose on an unsuspecting public. These range from mere ethical urgings (Mitcham, 2009) to fairly full-throated polemics (Winner, 1986). Of course, the roots of philosophy of technology as a field are intimately tied to this kind of critique (Mitcham, 1994). Seen at its heart, the argument schema is straightforward and often of the following form: Engineer X was instrumental to the creation of artifact Y, Y had Z damaging consequences, and X should have anticipated Z by modifying or not inventing Y. Elsewhere (Goldberg, 2009), I have taken on certain elements of one version of this type of argument in more detail, but the point here is to consider the application of this "engineering ethics schema" to philosophers.

Let X now be a philosopher, Y be an idea or argument, and Z be an undesired consequence of the use of Y. Should philosopher X have anticipated Z by modifying or not arguing Y, in an analogous way to the engineering ethics schema? There are a variety of issues to explore as to whether the two situations are analogous, and the paper considers key similarities and differences, but one conclusion of the work is that ideas often have the same unpredictability of consequences as artifacts, and it seems inconsistent to scrutinize engineers and engineering work without scrutinizing philosophers and philosophical work in a similar manner.

The paper continues, tackling the aforementioned definition and taxonomy and finds them to be wanting in a similar way. This leads to the conclusion that a kind of silver rule of cross-disciplinary consistency should be used by engineers and philosophers, both, or other pairwise groupings across disciplines who might want to collaborate in relative peace and consistency: "Do not criticize other disciplines, discipline members, or disciplinary results in ways you would not have done to yours."

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Challenges in Sustainability Engineering—Design for Whom, How and Why?

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What does it mean to "do" sustainability engineering? Often the core design questions are the same as those asked in all engineering design projects – for whom is the project and how can it meet user expectations? However, identifying user wants and needs can be particularly challenging in sustainable infrastructure and development projects in communities. Furthermore, the sustainability engineer may find themselves questioning the rationale for the engineering project in the first place, wanting to explore trade-offs among various opposing sustainability outcomes, e.g., environmental, public health, socio-cultural and economic impacts. Through field experiences in implementing sustainable infrastructure projects internationally and in the US, I will explore some of these questions and their relationship with ethics. I will also discuss an inter-disciplinary sequence of three courses in sustainable infrastructure, presently being implemented at the University of Colorado Denver that aims to provide the space for engineers to ask and answer some of these complex questions.

Engineering as Willing

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Science is widely perceived as an especially systematic approach to knowing; engineering could be conceived as an especially systematic approach to willing. The transcendental precepts of Lonergan (1957) may be adapted to provide the backdrop for this assessment. Attentive experience, intelligent understanding, and reasonable judgment lead us to adopt beliefs about how the world was in the past and is now; considerate deliberation and responsible decision lead us to make choices about how the world will be in the future. This framework recognizes the interactions between knowing and willing, as well as their distinctions, which become evident when comparing the scientific and engineering methods.

Scientists observe natural phenomena, propose hypotheses in an effort to explain them, and conduct careful experiments to test their theories. Although the will is implicitly involved, the intellect is primary, because the goal is ideal–additional "objective" knowledge. According to Koen (2003, p. 28), engineers engage in "the use of heuristics to cause the best change in a poorly understood situation within the available resources." Although the intellect is implicitly involved, the will is primary, because the goal is pragmatic–some "subjective" outcome; knowledge serves mainly as a necessary but insufficient means to that contingent end.

In fact, as Goldman (1991) notes, technology and innovation are generally dominated by market-driven value assessments, rather than by technical knowledge. Even when managers or clients are engineers by training, the decisions that they make inevitably reflect the agendas and priorities of the organizations that they serve–not necessarily the capabilities and limitations of the engineers whom they supervise or retain. As a result, engineering tends to be instrumental in nature; it is exploited by non-engineers to achieve their own objectives, which may be quite arbitrary. In other words, the willfulness of engineering is both enabled and restricted by the willfulness of the institutions that appropriate it.

Koen (2003, p. 28) suggests that a heuristic is "anything that provides a plausible aid or direction in the solution of a problem but is in the final analysis unjustified, incapable of justification, and potentially fallible." This formulation reflects how engineering is intrinsically at odds with the dominant tradition in Western culture, which–as Goldman (1984, 1990, 2004) points out–favors certainty and universality over probability and particularity; i.e., abstract knowledge over concrete know-how. While heuristics cannot be "proven" in the absolute sense, their utilization is legitimately warranted, frequently on the grounds of successful past implementation.

Each individual engineer has a unique collection of relevant heuristics at his or her disposal, along with "meta-heuristics" for selecting which heuristics are most appropriate in a given set of circumstances. When these are combined to facilitate translating a client's technical and non-technical requirements into a viable solution that adequately accounts for uncertainty and satisfies all applicable constraints, they constitute what Addis (1990, pp. 37-50) calls a design procedure. This is analogous to a scientific hypothesis; however, seemingly identical design procedures can have diverse outcomes, and different ones can produce quite similar results.

Most design procedures include the development of mathematical models that are supposed to capture the important aspects of reality. The engineer's challenge is to ascertain what those features are and what assumptions and simplifications can safely be incorporated in order to keep everything manageable, while still yielding a meaningful assessment of likely performance. Although analysis of a model is usually straightforward, conforming to fundamental principles derived from science, its initial construction and subsequent adjustment require “the conscious use of skill and creative imagination”–the dictionary definition of art (Merriam-Webster’s, 1993).

The bottom line is that engineering is not deterministic; it routinely involves selecting a way forward from among multiple options when there is no one “right” answer (Addis, 1997). Consequently, attempts to apply a theory of rationality to engineering (e.g., Kroes, Franssen, & Bucciarelli, 2009) are probably misguided; intentionality seems like a more appropriate concept. Design–in fact, all human behavior–is ultimately governed by motives, rather than reasons. Although common usage treats these two terms as virtually synonymous, the prevalence of the latter in both ordinary and philosophical discourse reflects an ancient prejudice that subordinates action to contemplation; i.e., willing to knowing.

As members of the profession that exemplifies willing, engineers should strive to resist and reverse this tendency. Specifically, Addis (1990, pp. 30-36) advocates abandoning the widespread notion of a “gap between theory and practice” in favor of an alternative classification: engineering science vs. engineering design. The essential difference between these two activities is not in the types of knowledge that they employ, but rather in their distinct purposes–further understanding and explaining the world vs. efficiently producing useful artifacts in a context of incomplete information.

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Debunking Contemporary Myths Concerning Engineering

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Efforts to understand the human activity we call engineering and to develop a philosophy of engineering are hampered by a myriad of myths put forth by a vocal group of the uninitiated. One oft-heard and over-used example will substantiate this point. Almost weekly we read in the newspaper or hear on television that “engineering is applied science” in spite of the fact that engineering existed in the earliest civilizations and science was arguably invented by the Ionian philosophers about the 6th century B. C.. Many similar ideas concerning engineering are demonstrably false. They block a true understanding of what engineering actually is and inhibit the development of a Philosophy of Engineering. The objective of this paper is to debunk some of the most egregious of these contemporary myths.

Engineering is best defined in terms of behavior; it is an activity; it is something an individual does. If we look in on an individual and see that he or she is doing certain things, we can infer that he or she is an engineer actively engaged in engineering work. Therefore, engineering should be understood in terms of method instead of one of the many common, egocentric, arbitrary definitions usually put forth. This simple fact is confirmed by the etymology of the word as given in a quotation from one of England’s most noted nineteenth-century engineers, Sir William Fairbain: “The term engineer comes more directly from an old French word in the form of a verb s’ingénieur . . . and thus we arrive at the interesting and certainly little known fact, that an engineer is anyone who seeks in his mind, who sets his mental powers in action, in order to discover or devise some means of succeeding in a difficult task he may have to perform.” An accurate understanding of what engineering is depends on an understanding of what an individual must be doing to be called an engineer.

To this end we begin our investigation with—but not belabor—a slightly revised definition of engineering that has repeatedly appeared in the literature as a starting point for our consideration, to wit: “The engineering method is the use of state-of-the-art heuristics to create the best change in an uncertain situation within the available resources.”(Koen 2003)[1] and then discuss important incorrect notions about engineering or myths prevalent today.

Examples of some of the myths that will be considered are the claims that engineering (1) is based on trial and error, (2) is applied science, (3) is of relatively recent origin, and (4) is limited to artifacts as concrete objects that persist over time.

To support the rejection of these claims, key concepts such as the change in the state-of-the-art (sota) and the importance of resources in engineering derived from the proposed, slightly modified definition of engineering method will be used to make ideas clear.

As two concrete examples in this presentation: (1) photographs will be used to demonstrate how the sota changed over time from the first colonnade designed by an engineer with its supporting buttresses and ramps for construction to the classic, free standing Greek columns of the Parthenon as predecessors of the modern columns of today, and (2) a demonstration using Nabisco Wafers will allow us to appreciate how the maximum size of enclosed space was critically affected in different

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[1] For a consideration of this definition of engineering and its relationship to other methods, specifically, to universal method see the reference (Koen 2009).

cultures over time by the available resources at the engineers' disposal. Any analysis of engineering that does not include at the very least the two concepts, the sota and available resources, is seen to be incomplete and, hence, flawed.

In the course of our investigations, we will meet the oldest engineer who ever lived whose name is known, see an actual record of his name written in the historical record, examine his engineering work, note the changes in sota he provoked, see how he was limited by available resources, learn what kind of engineer he was, and then—finally—stare directly into his face. Surprisingly, we have all heard his name and seen his portrayal in well known movies by one of the most celebrated actors of all time.

This analysis is not based on idle conjecture. It is substantiated by extensive quotations, images, and documentaries from the most reputable sources such as the History Channel, the National Geographic Channel, the Discovery Channel, the Smithsonian Encyclopedia, and Wikipedia.

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Fitting Engineering into Philosophy

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According to Wilfrid Sellars, “The aim of philosophy is to see how things in the broadest possible sense fit together in the broadest possible sense”. One of the things he concentrates on fitting together with common sense and the concept of a person is science. In this paper I explore how engineering fits together with the rest of the things with which we are concerned, such as persons, science, charity, science, religion, morality, death and taxes, etc. The problem is this: even in a technological society such as ours, engineers are not viewed as integral to that society. While engineers are understood to be critical for technological development in some sense, how they, as persons doing what they do, fit into our worldview is somewhat schizophrenic: we know engineers are necessary, yet we think of them as somehow now they same as the rest of us.

Part of the problem is a lack of understanding what engineers do. Engineers design and build things that hopefully will improve our living conditions. In that they are like many others, teachers, nurses, physicians, ministers, who seek to improve the human considtion. But they differ in so far as they approach solving problems quantitatively, or, as some see it, coldly.

I will show that the processes engineers use to solve their problems, are the same ones we all employ. If at bottom our thinking is fundamentally alike, the perception of difference will be harder to maintain. So the point here is to fit engineering into our common worldview by arguing that engineers think just like the rest of us. Thinking like the rest of us means that they ought not to be considered different. In that way we can begin to incorporate an apprceiation of engineering into our appreciation of the other accomplishments we have achieved, helping to see how it all fits together.

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The Meaning of a Brick: Systems Thinking for Engineering

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From the Great Wall of China and Roman aqueducts to early 20th century precursor “skyscrapers,” bricks have been and still are the building blocks of societies. While any civil engineering student understands a brick in terms of its materials, uses and characteristics, few understand its meaning in terms of its environmental, social, and economic relevance. This, however, is exactly what engineers need to know to help build a more socially and environmentally just (i.e., sustainable) future, and systems thinking provides a means to that end.

Systems thinking is not new to engineering, but it has primarily been applied to the analysis of technological systems (e.g., transportation, weapons, communication) (Hughes, 2004). Yet, these technological sytems are nested within social and ecological systems, and these connections are largely ignored by engineers. The result has been environmental devastation, economic disparity and social disfunction on a global scale.

The meaning of a brick, therefore, is defined by more than the infrastructure system of which it is part. It is also defined by the economic and social forces that make the infrastructure possible. In the above examples, the meaning encompasses exploited labor forces. The Great Wall, a 4000 mile defensive structure, was constructed by millions of soldiers and peasant laborers. The workforce for Roman aqueducts also consisted of soldiers, peasants and slaves. In the 19th and 20th century, much of the working labor force in the US was poorly paid immigrants and child laborers; a practice that continues throughout the world today. All these examples also include women’s productive labor (e.g. cooking, washing) which is generally considered as “non-work” (Federici 2009).

The economic and political forces that promote large-scale engineering projects are all too often based on widespread social and environmental injustices. The Great Wall was built to protect the power and affluence of the ruling elite against impoverished outsiders. Roman aqueducts were the result of a failed waste management system that left local waterways polluted and necessitated the transport of clean drinking water from hundreds of miles away. Aren’t examples of these practices evident today in the US-Mexican border fences and our own polluted waterways and failed waste management systems? Like their ancient forbearers, modern engineering projects (e.g., mega dams, agricultural engineering, mining operations, timbering) also result in the displacement and exploitation of poor and indigenous people, as well as the destruction of important ecosystems.

The meaning of a brick also relates to the history of mechanization and global capitalism. Global capitalism benefits the wealthy at the expense of the poor, and mechanization displaces manual labor. In impoverished communities, it is manual labor that keeps families fed. The brick houses in the northeastern US built in the 18th and 19th centuries were made by a local workforce from local sources. Thus, they were sustainable and made economic, environmental and social sense. Nowadays, bricks at the “local” Home Depot are often made in China and transported 10,000 miles before finding their way to someone’s patio. Unsustainable oil energy for today’s brick production and transportation has replaced past local sustainable human and animal energy.

The meaning of a brick includes social unrest and civil disobedience; the brick as a weapon for those without power and hope. This was evident in Haiti and Egypt when local food prices soared, and Haitians and Egyptians took to the streets, hurling bricks and rocks (Smith 2008). Many factors were blamed, but the real systemic issues are an unsustainable agricultural system that includes land and soil mismanagement, unsustainable water use and an over-reliance on engineered-enabled fossil fuel dependent practices (e.g. mechanization, fertilizers, pesticides), as well as the power politics among corporate, government and other wealthy elite. The devastation from the recent earthquake in Haiti also needs to be questioned as more than a failure of bricks and mortor. As Smith (2010) notes, US policies disrupted local agriculture and forced hundreds of thousands of rural Haitains to city slums in search of jobs (albeit in low paying sweatshops in US export processing zones) in addition to other policies (e.g. US support of Haitian dictators). A city of 50,000 in 1950 grew 40 times to two million in 2010. Thus when disaster struck the devastation affected greater numbers.

Like technology, a brick with all its meanings and connections is many things, but it has never been neutral. Questioning, as Heidegger (1954) notes, builds a way of thinking. Questioning the meaning of a brick is a lesson for all engineers to see engineering as more than another technological fix in an increasingly mechanized world. A systems thinking approach requires social justice and true environmental benefit as paramount components of every engineering solution, for that is the only way to long-term economic health for all. In this new millennium, an engineer must be a leader of sustainable approaches; not just another brick in the wall.

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Sustaining Engineering Codes of Ethics for the 21st Century

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The National Society for Professional Engineering revised its code of ethics in 2007 to encourage engineers to "adhere to the principles of sustainable development." The American Society of Civil Engineers and similar organizations have stressed the need for engineers to support these principles in the course of their professional practice. However, further calls for engineers to consider the related issues of social justice and environmental justice in particular, meet with considerable debate over what this means for engineering codes of ethics (Schrerer, 2003). This is particularly true given the evolution of the term sustainability as encompassing not just the environment, but also the economy, and society (Allenby, 2009).

Some take these additions to the codes of ethics to be redundancies, believing that the long-standing code commitment of professional engineers to "hold paramount the public's welfare" already includes a commitment to sustainability. Others argue that while sustainability can be "engineered," justice is a societal goal beyond the scope of the engineer Ageyman, 2003 & 2005). Some of those who agree that some aspects of these additions are not redundant argue that placing the need to adhere to such principles after and outside of the "paramountcy clause" has the impact of devaluing such adherence in professional practice, perhaps even to the point of making such adherence supererogatory (Vesiland, 2002). Much of the debate centers around the question of just what "sustainability" means beyond the fairly empty idea that sustainability is a critically important concept for the 21st century (Allenby, 2009; Gunn, 1998). With no consensus over what sustainability means, it becomes highly questionable how this idea can generate a clear sense of direction for engineering solutions, for framing such problems to begin with, or for otherwise operationalizing such goals.

In this paper, we suggest that the addition of a commitment to sustainability within engineering codes of ethics is not redundant, particularly when seen from a viewpoint of social and environmental justice. "Holding paramount the public's welfare" presents the engineer with an aggregate goal for that community affected by the engineering project, and does not imply nor necessitate greater equality of benefits and harms (Vallero, 2006). A step in the direction of encouraging engineers to give more of a priority to justice considerations in their professional practices would be to make commitments to sustainability within engineering codes of ethics on a par with commitments to public health, safety, and welfare. But how can this be done if the concept of sustainability is by its very nature highly contested?

We first explore the justice aspects of the three prongs of sustainability as they affect the traditional engineering design process and the consequences of engineered systems. We then look to Brian Barry (2007) and other social and political philosophers who have noted that in its contestability, the concept of sustainability is no different from justice and other normative concepts out of which theories are built and, we could add, used to construct solutions to social problems. Drawing upon these and other philosophical writings addressing the concept of sustainability (Herkert, 2009; Scherer, 2003), we propose that increasing the emphasis on the public responsibility of engineers to create a more sustainable and environmentally just future is not just a matter of simply expanding the set of professional responsibilities of engineers, but also of integrating personal with professional virtues.

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Designing Evolving Engineering Systems

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How may scientists and engineers pursue new knowledge and continue to create technological innovations, but do so wisely? Webster's defines wisdom as the power of judging rightly and following the soundest course of action based on knowledge, experience, and understanding. Because it is impossible to know the full consequences of any technological innovation far into the future, how might decisions be made in a way that encourages technological innovation yet embody strategies to anticipate, interpret, and mitigate possible environmental, health, safety or ethical concerns and do so in a timely manner (Collingridge 1992, Simon 1996)? For social decisions regarding technological innovation to be wise, a clear understanding of what is known and unknown and the reasoning entailed is needed. Asking whether society is pursuing innovation wisely is a way of holistically considering how a technological innovation may change civilization. One may look back at the great engineering achievements of the 20th century and ask, if society had asked how these technologies may be developed wisely would they have been developed in the same way (Constable and Somerville 2003)? The Grand Challenges for Engineering in the 21st century are partially a response the problems created by the great engineering achievements of the 20th century (National Academy of Engineering 2010).

Computer scientist Bill Joy in a 2000 Wired article, The Future Doesn't Need Us, and in a subsequent op-ed in the Washington Post argued that the relentless world-wide drive for innovation in the name of competitive advantage creates knowledge that may have malevolent as well as benevolent uses and effects (Joy 2000a, Joy 2000b). Although The Future Doesn't Need Us was much discussed at the time it was published and still is discussed, the recommendations that Joy suggested in the follow-up op-ed as a way to balance innovation with safety have gone largely unfulfilled. One recent example as a step in the right direction is an announcement that that the United States Office of Science and Technology Policy is forming an interagency group on emerging technologies to better understand the implications of these technologies (AAAS 2010). The concern that Joy raised ten years ago was in the context of genetic engineering, nanotechnology, and robotics. A main point was that the effective management and governance of technology was equivalent to the effective management and governance of knowledge. This insight has implications that extend beyond genetics, nanotechnology, and robotics to the management and governance of complex, large-scale engineering systems or socio-technical systems because these technologies may be components in agricultural, energy, security, transportation, waste, and water systems.

What is the management and governance of knowledge and how is it related to the management and governance of science and technology? In a world where technological innovation is increasingly viewed as essential for prosperity and that increasing numbers of firms and nations are developing innovation systems to obtain competitive advantages, how will society organize to understand the implications of scientific and technological advance and act to develop concurrently safeguard systems? How stakeholders learn about technological innovations and its relationship to engineering systems is a central challenge in achieving intelligent and wise societal decision making. To engage in meaningful dialogue about strategies to best manage and govern technology and engineering systems, one must know what one is talking about. Specifically, how do stakeholders and decisionmakers learn to distinguish what makes sense from non-sense or hyperbole while leaving open the possibility of novel interpretations? How is all the relevant knowledge brought to bear on a decision situation? What knowledge is considered relevant and why? Guston and Sarewitz (2001) describe a process they term real time technology assessments as one strategy society may develop to increase its capacity to respond to technological innovation and identifies the need for early warning systems. According to Simon, "The real design problem is not to provide more information to people but . . . [to get them] the information that is most important and relevant to the decisions that they will make. The task is not to design information distributing systems but intelligent information-filtering systems."

Also, according to Simon (1996), the success of adaptive systems rarely depends on prediction for coping with the future, but rather on homeostatic and feedback mechanisms. Learning is a form of feedback and in designing evolving engineering systems one would want to learn about certain qualities of a system, known as the "ilities," which include flexibility, scalability, reliability, recyclability, maintainability, quality, and safety, as desirable characteristics of an engineering system (Moses 2004). This paper argues that designing evolving engineering systems wisely is contingent upon the development of learning systems that support knowledgeable deliberation. Advance personalized learning is one the Grand Challenges for Engineering and one target for its achievement may be in support stakeholder learning of complex, engineering systems.

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Uncertainty in the Design of Non-prototypical Engineered Systems

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Engineering design must be performed under conditions of uncertainty, some of which are obvious and some of which many engineers may never have consciously considered. The level of uncertainty for non-prototypical engineered systems, or "one-off" systems, is even greater because prototype testing is not possible (Blockley 1992). In this paper we consider the uncertainties facing engineers who design non-prototypical engineered systems and the ways that engineers manage those uncertainties in a manner that allows design decisions to be made.

Uncertainty can be separated into two categories: aleatory, related to luck or chance, and epistemic, related to knowledge (Der Kiuerghian and Ditlevsen, 2009). This breakdown has an impact on how we handle the various types of uncertainty and the way we think about each type. We consider five broad sources of uncertainty: time, statistical limits, modeling, randomness, and human error (Bulleit 2008). Some uncertainties are explicitly dealt with using codes of practice (e.g., Ellingwood et al. 1980), some are dealt with through quality control measures, and some are dealt with in implicit ways that we often do not think much about, e.g., heuristics (Koen 2003).

Codes of practice are used to help deal with uncertainties caused by randomness, statistical limits, and some aspects of time and modeling. The level of complexity of a code of practice has an impact on the uncertainty in the design (Elms 1999) and must be considered in discussion of design uncertainty. Uncertainty is also induced by contingency (Simon 1996). All designs are contingent because the object being designed does not yet exist so the design is being done using a visualization of the object. Contingency is one of the major differences between science and engineering: science studies objects that exist in nature, whereas engineers must work with objects that do not yet exist. It is contingency that means that truly unique structures, whether designed to a code of practice or not, exhibit more uncertainty than structures that are similar to existing systems (Shapiro 1997). Randomness can be dealt with using probability concepts such as exclusion values, extreme values, and return periods. These concepts allow us to deal with uncertainties in loads, other environmental effects (e.g., rainfall), and variability in material properties. Human error is dealt with using quality control methods, such as peer reviews and construction inspection. Human error is a major contributor to the uncertainty in the design and behavior of structures (Petrosky 1982, 1994), and many failures are primarily due to it. Model errors include a range of types including limited knowledge (epistemic uncertainty) and conceptual errors. Many model errors, such as conceptual errors in the development of a structural model, could be classified as human error.

Further examination of the influence of time might lead one to consider that the difference between non-prototypical and prototypical systems is simply the time scale over which they are built and used. Billington (1983) distinguishes between machines and structures. Machines have a shorter life and are modified more rapidly than are structures. Virtually no machines from the 19th century are still in regular use, but there are a fairly large number of bridges from that era still being used. But, we have learned a lot about bridges since that time, so in a way the past bridges are prototypes for the future bridges. If we think about it this way, then the controlling factor is the feedback that the engineer gets on the design. If we can build prototypes, then the feedback time is short enough that we can incorporate the feedback into the design itself. But, the feedback on bridges has a long cycle that can only be incorporated into later designs. In some cases, the feedback comes from a failure. The first Tacoma Narrows Bridge gave a significant amount of feedback to designers of suspension bridges.

The way engineers approach uncertainty has philosophical, technical, and even ethical implications for the design and construction of non-prototypical engineered systems. Practitioners of the design of non-prototypical engineered systems would be wise to take some time to reflect on their designs and the thought processes that they used to justify their design (Schon 1983). This reflection could be a useful form of feedback for future designs.

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Identification and Bridging of Semantic Gaps in the Context of Multi-Domain Engineering

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The communication challenge frequently encountered within engineering projects is often threefold: The communication with the customer or stakeholder, between different representations of the artifact to be designed in a specific domain and between members and representations from different engineering domains. This paper makes an attempt to localize and to improve the treatment of the communication challenge encountered in multi-domain or interdisciplinary engineering by applying a generalized notion of "semantic gap". The main focus of the paper is on the treatment of the semantic gap between different engineering domains. First, the concept of "semantic gap" is generalized on the basis of existing definitions. Second, different types of semantic gaps are identified within multi-domain engineering projects and how they are currently bridged. The possibility to further bridge the semantic gaps between different engineering domains is exemplified by the usage of the modeling language SysML. It is shown that the concept of "semantic gap" helps to use modeling languages more effectively by better identifying their possibilities and limits in improving cross-domain communication. This holds the potential to further improve the communication between engineers.

Several definitions of "semantic gap" are available in the computer science literature (Dorai, 2003), (Spinczyk, 2008). From these publications, the following more general definition can be obtained: A "semantic gap" is the difference in meaning between constructs formed within different representation systems. A representation system can be e.g. a natural language, a formal language or a "proper language" within an engineering domain (Bucciarelli, 2003).

Multi-domain engineering is encountered in projects, in which engineers with a background in more than one domain are involved. This can be exemplified by mechatronics engineering, which is a very common form of multi-domain engineering. Most of the mechatronics project teams consist of engineers with a background in the mechanical, electrical and software engineering domain. This type of projects will be considered in this paper.

Within multi-domain engineering, different kinds of semantic gaps can be identified. First, the semantic gaps between the expressed user/customer/stakeholder needs and the engineering solution. Needs are usually explicitly expressed in natural language, whereas the engineering solution is represented by elements from the technical domain. Second, the semantic gaps within a domain, where different representations of an artifact are used. This can be the difference between a functional or the physical representation of an artifact. Third, between domains, where aspects of the artifact to be designed are described in different domain specific languages. An example would be the representation of the physical structure of a satellite in a Computer Aided Design software and the representation of the satellite software within the Unified Modeling Language (UML).

What attempts exist to bridge the different kinds of semantic gaps? The gaps associated with the first point are extensively treated in existing literature on requirements engineering (Wiegers, 2003), (Pohl, 2008). The main task of requirements engineering is to bridge these gaps by different methods like interviews, rapid prototyping and reviews. Gaps related to the second point are considered in the computer science literature (van Amstel, 2008), (Ehrig, 2005). There are also attempts made to introduce a higher semantic layer called “features” into Computer Aided Design systems in mechanical engineering in order to tie the functional to the physical representation (Shah, 1995). Methods for bridging the gaps associated with the third point are implicitly addressed in the systems and software engineering literature by different modeling languages (Bruegge, 2009). Modeling languages are intended to facilitate the communication between different domains by representing domain specific knowledge within the language.

This leads directly to the question, to which extent the above mentioned engineering domains (mechanical, electric, software) make use of similar objects. Several commonly used types of objects can be identified: Requirements, functions, relations etc. Using this cross-domain “vocabulary” in a modeling language supports the engineer’s attempt to understand a representation in this language, containing elements from a different domain. However, to judge whether the content of the representation makes sense or not requires domain specific knowledge, which poses a limit to cross-domain understanding. This observation can be related to Tarski’s truth definitions and other semantic concepts like the one developed in (Hodges, 2009). These findings are exemplified by a representative situation within an engineering project in which Systems Modeling Language (SysML) diagrams are used.

On the basis of these insights, it is believed that new semantic layers based on modeling languages, which include cross-domain “vocabulary” can help to further close the semantic gaps between different domains and thus improve the communication between engineers.

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Innovation Systems and Philosophy: Encouraging an Engineering-Centered Strategy for Energy Innovation

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Conceptions about what science, engineering and innovation are can play a significant role in how societies use technology to solve problems. One potentially harmful conception occurs by placing too much emphasis on science, and viewing it as definitive of both engineering and innovation. Conceptually, philosophers of technology have argued that science and engineering have distinct natures; while both fields may rely upon analytical tools that include idealizations, iterative experiments, literally false assumptions, and the need to use a merely workable solution rather than an optimal one, engineering should not be considered a derivative of science, and is deserving of conceptual study (Mitcham and Mackey 1983, Wimsatt 2006). Practically, innovation policies have long been influenced by the vision that science is the key to innovation. Despite being soundly rejected by academics, Vannevar Bush's linear model of innovation, where a foundation of basic science leads to applied science and innovation, still dominates innovation policy.

Mindful of society's need for energy technology innovation to solve the problem of climate change, this paper will examine key principles for successful innovation systems. In contrast to what I will call the current existing science-centric approach, I will argue for a more engineering-centered approach toward innovation, based upon insights from the innovation studies literature (CSPO/CATF 2009; Lester 2009). Innovation is a complex process, involving many actors but primarily centered in the private sector, and it comes most frequently from incremental learning that happens when technology is deployed in the field. In established technological fields, innovation occurs naturally, with private industry evaluating and implementing new techniques and learning from the experience in order to increase profitability and competitiveness. From this perspective, what is traditionally seen as science has a valuable but limited role to play; engineering, and the system wide learning that occurs in innovation systems, is the key to developing better and cheaper technologies.

In my presentation, I will first review US Department of Energy funding, polices and research in order to argue that US energy policy have not sufficiently encouraged innovation, instead focusing too much on research. I will then develop key innovation principles in the context of two case studies. The first case study will examine the role of the US government in encouraging the development of the internet, where government procurement, collaboration with the private sector, and competition amongst government agencies were key to successful innovation (Mowery Nelson and Martin 2009, CSPO/CATF 2009). I will then review the history of US research on creating synthetic fuels from coal, which represents a case where application of innovation principles was lacking (Cohen and Noll 1991). Lastly, I will argue for a more engineering-focused strategy for encouraging energy innovation today.

This analysis will represent both an ethical claim and a philosophical claim. The ethical claim is that the federal government should play an important role in encouraging energy innovation beyond conventional R&D funding, most especially through procurement, strategic demonstration projects, and by encouraging competition amongst government programs. As will become apparent in the case studies, the philosophical claim is that study of innovation systems is valuable for understanding engineering and technological development. Further, there are other reasons why philosophers should care more about innovation studies, as philosophers can push for clearer understanding of innovation and can better explore the societal and ethical dimensions of energy systems change.

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Quantitative Design Tools in Engineering Design of Innovative Technologies

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Currently, innovative technologies, such as nanotechnology, get much attention in public and political debates. These new technologies are exiting, because they offer the possibility of many societal benefits. For example, nanotechnology promised to reduce energy usage, improve medical care, enhance waste treatment, and lower costs of electronics. Alongside these benefits, concerns have been expressed about the potential risk associated with new technologies. Nanotechnology has raised various issues, including concerns about toxicity, environmental impact, privacy issues, human enhancement, global economical and political effects, as well as doomsday scenarios (The Royal Society, 2004). Most of these issues have in common that they involve ethical questions of equity, fairness, and safety.

Engineers that design products and processes using innovative technologies are thus confronted with ethical questions. In the design process, engineers try to fulfil design requirements and criteria that include ethically relevant criteria, such as safety or sustainability. In many cases, the engineer has to make trade-offs or compromises between these requirements and criteria. These decisions are ethically-relevant (van Gorp & van de Poel, 2001). In normal designs, in which the known operational principle and/or normal configuration is utilised, generally there is a normative framework to guide the ethically relevant decisions (Grunwald, 2001). However, in applying innovative technologies such framework is often missing or found to be inadequate.

The issues raised by innovative technologies are also plagued by uncertainty about possible positive or negative consequences of the new technology. In the initial stage of development and implementation, the potential effects of technological application are surrounded by uncertainties. An illustration of such existing uncertainty is the continued discussion about the dose metric that ought to be used for toxicity testing of nanoparticles (Wittmaack, 2007). Also large uncertainties exist on the long-term effects of nanoparticles on the environment and human health (Singh et al., 2009). These uncertainties can be categorised in four main groups, knowingly: lack of knowledge probabilities of effect are unknown, ignorance unknown effects, complexity uncertain causal relation, and ambiguity uncertainty in the judgement (Renn & Roco, 2006). Engineers that work in the field of innovative technologies thus have to cope with these different kinds of uncertainties that surround their engineering design.

In case studies, it was explored how design teams, of graduate and post-graduate students from the TU Delft, made such ethically relevant design decisions under uncertainty. In all cases, the designers used quantitative decision-making tools, such as multi-criteria analysis and quality function deployment house of quality. However, these tools have been strongly criticised because of their methodological problems due to Arrow's Impossibility Theorem (Franssen, 2005; van de Poel, 2007). A second difficulty of these tools is related to the trade-offs made between requirements/criteria are value laden. As such the approaches presuppose the problematic notion of value commensurability (Aldered, 2002). A third problem with these quantitative tools is that these approaches are ill-equipped to deal with two types of uncertainty, namely ignorance and complexity, mainly due to the focus on quantifiable aspects of design requirements and criteria.

The design engineers from our case studies were unaware of the criticisms on the quantitative tools they regularly apply. Some engineers nonetheless had a general notion that the decision tools cannot be applied without further deliberation. They seem not to apply the tools to the full extent and/or even used them for a different purpose. For instance, a design team utilized the multi-criteria analysis as a kind of persuasion tool to convince the client of the design alternative of their liking. The alternative application of the design tools does not lead to ethically more desirable decisions, but even hinders the desired ethical deliberation. Therefore, it may be argued that tools, such as multi-criteria analysis and quality function deployment, should be employed more subjectively to bring ethical issues under discussion. Alternatively, other subjective approaches could be adapted to specifically facilitate design decisions in innovative technologies.

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On the Epistemology of Breakthrough Innovation: the Non-Linear and Orthogonal Natures of Discovery

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One of the most important roles of researchers in technology-based companies is to develop innovative new products and processes to either increase revenue or decrease cost. However, while some have begun to consider how engineers and scientists "know," (Vincenti, 1990; Mitcham, 1994) as noted in our WPE 2008 presentation, (Vojak, Price and Griffin, 2008) most practitioners and researchers of corporate innovation carry unarticulated, less-than-fully developed assumptions about this topic.

As with our earlier epistemological study, we address breakthrough innovation in industry, and the observations described herein arise from reflection on the results of the research of Griffin, Price and Vojak, (see, for example: Vojak, et al., 2006; Griffin, et al., 2009) conducted over the past seven years and based on over 125 in-depth interviews as well as a large sample survey. This body of research investigates individuals who have repeatedly conceived and commercialized breakthrough new products in large, mature engineering-intensive firms, and has led us to a clearer understanding of how corporate innovation occurs in practice.

So, what do we know about breakthrough innovation that might reveal new epistemological insight?

First, truly innovative output is disruptive, unexpected in its appearance. (Christensen, 1997; Schumpeter, 1947) We know that small, apparently insignificant insights can pave the way to significant innovations. We know that breakthrough innovation is a messy, complex process that does not follow neatly-defined paths. Finally for the purposes of this discussion, we know that, in an effort to stimulate creative, innovative output, many recommend the process of "brainstorming." Interestingly, these insights suggest that the underlying nature of innovative discovery can be illustrated mathematically by using chaos theory, (Strogatz, 2001) an important implication of which is that some form of non-linear process must be present in the system.

Second, breakthrough innovators bring both depth and breadth in their disciplinary knowledge base. While academic researchers often are characterized by their profound depth of insight in one field of study, industrial innovators are often described as "T-shaped" in that they know a great deal about their primary discipline and something about many, other disciplines. Further, some have observed that breakthrough innovators are "π-shaped" or "m-shaped" in that they exhibit significant depth in additional fields. Interestingly, these intuitive descriptions have the appearance of a spectrum, with the spectral profile used to represent the depth of knowledge in unique, distinct disciplines, an implication of which is that multidisciplinary knowledge of the type observed in breakthrough innovators can be illustrated, if not represented by the sum of a set of orthogonal, independent functions, one function for each entirely distinct discipline within which something is known.

While each of these two individual observations is of modest interest in its isolated ability to describe breakthrough innovation, when taken together, a richness of insight emerges.

What brings these observations together is that breakthrough innovators "connect the dots." That is, they gather and synthesize information and insights from many, disparate disciplines and sources in a way that they see a whole that is greater than the sum of its parts. Such transcending and creatively cross-fertilizing or mixing of disciplinary insight has been recognized, as well, by others in the literature. (Fleming, 2007; Johansson, 2004) Further, it has been recognized anecdotally by practitioners who talk about the "cross terms (the xy terms)" in a polynomial as illustrating significant value in the creation of new ideas. In the present work we take this understanding to a next level. By analogy, we note that several systems, ranging from musical instruments to wireless communication systems, display – and critically depend on for their operation – behavior that is mathematically similar to what we suggest as being characteristic of the nature of breakthrough innovation.

In this presentation, the authors use the non-linear and orthogonal natures of discovery to mathematically illustrate, by using Matlab simulation (`http://www.mathworks.com/products/matlab/`), several features of breakthrough innovation – revealing both the epistemological and managerial implications of these features, as well as discussing some of the limitations of the current model.

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Engineering Hubris: Adam Smith and the Quest for the Perfect Machine

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Adam Smith observes, in his The Theory of Moral Sentiments, that humans are sometimes infected with a powerful drive to perfect a tool, device, or implement, to a point far beyond what economics or practical needs would deem prudent. This can manifest as the quest to make some invention work in a way which is infinitely smooth, neat, simple, or efficient, according to certain perspectives or parameters, even when this is not necessary for reliable functioning or achievement of the invention's intended goal, and might sometimes interfere with it. At times this drive has doubtless led to breakthroughs which advanced human needs and made earlier versions obsolete, but at others it has led to the obsessive overriding of human needs by the engineer's (or manager's) quest for an unachievable "perfection" which did not take into account all relevant factors, but focused on only a few, which turned out to not be the most important ones. In such cases, the perfect can truly be the enemy of the good.

I illustrate my point with four case studies. (1) The quest to build a sea-level canal in Panama, continuing the "conquest of nature" theme which was successful in Suez, but met with far more hostile conditions in the new world, which the builders did not attempt to compromise with until it was too late to save the project. The attempt led to financial ruin, political scandal, and the deaths of thousands, until the project was abandoned for a more practical lock canal completed by the U.S. government. (2) Buckminster Fuller's plan to build inexpensive post-war housing with silo-like structures, suspending most of the weight off a central pole and hence leveraging the value of tensile strength instead of weaker and more traditional compressive structures. This plan might have found a niche except for his refusal to commit to an earlier and potentially feasible design, insisting instead upon further revisions to perfect or idealize the concept, which scared off potential investors and scuttled the project. (3) Robert Moses' obsession with a vision of directly connecting highways with uninterrupted flow, to be constructed at the cost of cutting through the dense and vibrant urban corridors of New York City. This destroyed many neighborhoods and possibly stymied alternate transit plans, until mass public reaction put a halt to the juggernaut of Moses' public works institutions. (4) The quest for a high technology, reusable space launcher, ideally a "single stage to orbit" craft, which has for decades pushed U.S. and other western nations into the development and use of technologies with far higher payload costs than was necessary, including the current design of the space shuttle. This centered our space program around technologies and institutions with questionable advantages over cheaper, proven technologies.

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The Historical Survey of The Role Which The Ethics Plays in Technological Stipulation

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Technology, as a means of transforming the nature substance, not only creates a new material civilization, but also alters the manner and conception of thinking, updating their ethical and moral content as well. Certain social ethics with relative independence has stipulation on technology. Taking the historical ethic's effect on technology as the clues, this article explains the different characteristics in different historical periods.

The ancient craftsmen technology constrained by Religious Ethics

The technology history is as old as the history of mankind. Hominid invented many important hand tools, master a variety of skills, but they do not recognize their own strength, instead, they attributed the technical invention and creativity to the "divine revelation ", or the help of their ancestors' soul. At the end of primitive society, the handicraft industry, gradually separated from agriculture, creating a number of specialized craftsmen engaged in manual labor. Particularly around 1400 BC, because of smelting iron technology's invention and application, the craftsmen become an independent social occupation, undertaking the responsibility for ancient technology invention and application.

Modern large engineering technology motivated by value of utilitarianism

At the age of large enginery technology, the objective of applying the technologies obtained the radical changes. It didn't take any longer for technology activities to meet crafts and farmers' their own needs but were the means to obtain the surplus value as its maximum. Obtaining the profits became ultimate force to motivate the invention and application for technology and earning money was the prime motivation for a capitalist to support and develop technology in order to bring economic interests for himself, consequently, pursuing interests was an essential trait during the age of large enginery technology. Consequently, the nature of the technology –pursuing the interests got the echoes from the ethical perspectives of utilitarianism.

Modern technology calls for ethical stipulation of an agreement of responsibility

The combination of technology and utilitarianism makes people possess unimaginable material wealth as well as produces anxious negative impact which embodies on the harm to mankind himself, mankind society and ecological environment. Modern technology is appealing to such kind of "ethics of duty". In the age of technology, with the help of technology, man's power are enhancing unprecedentedly, owing to mutual connection, all activities couple and become an socialized collective activities which effect affect the whole globe in space and impact the remote future in time. So, actors, behavior and the results have the intrinsic differences from the former activities done within the closed scope and thus put "responsibility " forward to the center of ethical theory.

The impact on ethics taken by new technology mainly embodies on the concept of “responsibility” which is getting more and more extensively and profoundly, it requires people reconsider the issue of moral duties.

In the first place, modern technology makes the “responsibility” have perspective to futureIn the second place, modern technology makes the “responsibility” have the value perspective to nature.In the third place, modern technology makes “responsibility” have the global perspective.

From the historical reviewing on the stipulated and restricted effects to technology directed by ethics, we are easy to find that the effective ways and contents that ethics apply on technology is changing with the change of technological system. Modern society has upgraded the technology to an absolutely necessary position, like a double-edged sword, it must bring mankind suffering disaster if it could be controlled properly. Consequently, we have to carry out ethical stipulation on modern technology. The stipulation, which was neither roundly conquered by ethics in ancient technological society nor was the echo for technology from ethics in modern society, needs to establish an effective accountability mechanism so that find out a rational moral yardstick for modern technology.

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The Nazi Engineers: Reflections on Technological Ethics in Hell

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Begin with this fact: engineers, architects, and other technological professionals designed the genocidal death machines of the Third Reich. The death camp operations were highly efficient, so these technological professionals knew what they were doing: they were, so to speak, good engineers. As an educator at a technological university, I need to explain to my students—future engineers and architects—the motivations and ethical reasoning of the technological professionals of the Third Reich. I need to educate my students in the ethical practices of this hellish regime so that they can avoid this type of ethical justification in their own professional lives to come.

In this essay, I examine several arguments about the ethical judgments of professionals in Nazi Germany, and attempt a synthesis that can provide a lesson for contemporary engineers and other technological professionals. I begin with Robert J. Lifton's groundbreaking account of Nazi doctors and the concept of "doubling" that he proposed as a psychological explanation (Lifton, 1986). But legal scholar Jack Sammons and historian Michael Allen offer alternatives to Lifton's model by focusing on the career of Hitler's architect and arms minister, Albert Speer, and on the working lives of mid-level SS managers and engineers (Sammons, 1992; Allen, 2002). Speer, in his memoirs, notoriously argued that he was a pure technocrat unconcerned with ethical and political tasks (Speer, 1970). Speer suggests that he should have rebelled against his technological training in order to be more ethical. Sammons rejects this model of "rebellious ethics" and argues that Speer should have embraced the ethical values of his profession—architecture—in order to be a good technological professional. In its concern for built environments that better human life, Speer might have found an ethical ground for resisting the evils of Nazism. Allen's argument further complicates this analysis: in his historical study of SS industrial policy, he learns that among SS managers and engineers there was a convergence between professional goals and political values. Nazi engineers believed that what they were doing was good: there was no need to rebel against the pure technique of their profession, nor was there a need to find another ground of value to resist the evils of Nazism.

The lessons for future engineers are problematic. I have argued in the past (Katz, 2005) that the death camps are a prime example of the political nature of technology. If all artifacts have politics (Winner, 1986), then whatever engineers create will embody a particular set of political values and ideologies. How does an engineer avoid the error of the Nazi engineers in their embrace of an evil ideology underlying their technological creations? How does an engineer know that the values he embodies though his technological products are good values that will lead to a better world? This last question, I believe, is the fundamental issue for the understanding of engineering ethics.

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Earlier Integration, Better Development—a New Trend in Governance of Nanotechnology

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Building on the model established by the ELSA programme of the Human Genome Programme, science policies in the US, Europe and elsewhere have in recent years manifest a trend of integration of social and ethical considerations with research and development (R&D) processes of nanotechnology (e.g. 21st Century Nanotechnology Research and Development Act 2003, USA; European Commission 2004; HM Government,2005; European Group on Ethics 2007), resulting in the US in the funding of a number of ELSA research centres and also many other research programmes in Europe.

Compared to earlier policy, what's new in recent policy for nanotechnology is that it goes further than requiring consideration and identification of ethical and social issues in scientific and technological research and development. Analysis of the societal and ethical implications of nanotechnology is positioned and expected to contribute to the R&D agenda and influence the further course of nanotechnology development influence the development of the technology. This role is to be much more than mere 'window dressing' and more than reactive.

For the field of ELSA Research of nanotechnology, this creates an enormous opportunity, though it also constitutes a significant challenge. How can the field go beyond identifying and considering ethical issues? How can nano-ELSA make a difference in the kind of technology that results from the research and development initiative?

There remain some concerns for the current ELSA research on nanotechnology: The first point is the role of ELSA research in the whole landscape of nanotechnology development. It's claimed that ELSA efforts intend to trigger better reflexivity within science community and also the awareness of the public participation. In this way, science and technology can embrace plural and diverse forms of knowledge and become more socially robust, and we human beings can have better science and technology in terms of human flourishing. However, since ELSA research on nanotechnology is funded by groups with strong interests in the success of nanotechnology, ELSA researchers take a great risk to be drawn into a role of servant for the nano-scientists or nano-engineers. But we cannot refuse the funding and refused to become one part of the nano-enterprise. Or else, we may lose the opportunity to engage in shaping the trajectory of nanotechnology. Then, is there a middle way? Is there any possibility to keep a distance from becoming a specific nanotechnology enactor? In my opinion, some of the ELSA researchers might finally become part of institutions, but there might still be some free-floating ELSA Scholars complementing, who regard the general shaping of nanotechnology as a collective experiment, and keep on reflecting the underlying purposes of nanotechnology.

The second point regards the content in current ELSA research. Currently, it seems that social scientists and their descriptive approaches play a major role in the ELSA research, especially on the early integration issue (Constructive Technology Assessment, Real-time Technology Assessment,etc.) In these research efforts, it remains vague about the exact organization of the discussion about the emerging nanotechnology which is still in its infancy, after different stakeholders have been invited to sit at table. Further, deliberative dialogue itself might not guarantee a more democratic science and technology development. To reach for a certain kind consensus could still be the goal for debates. A certain kind of normative dimension might need to be added in current sociology-dominated nano-ELSA Research.

In conclusion, early Integration of social and ethical concerns into the R&D of nanotechnology is a promising trend in governance of nanotechnology. Even if it turns out to be a small step, it is a step in the right direction, a step towards recognizing that decision making about the future of science and technology should involve more than a narrow range of interest groups. Nevertheless, before we go further, we need to clarify two points: first, the genuine goal of ELSA research; the actual challenges we might face when implement. Possible suggestions are recommended to embrace these challenges from different levels.

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The Governance of Nanotechnology in China: Problems and Countermeasure

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The Reform and Open policy has facilitated the development of Chinese S&T rapidly. Particularly, under the impact of globalization and knowledge-based economy wave, China is anxious to use its own predominance to upgrade industry configuration and step up its productivity level to a new height. Therefore, the whole nation has a strong desire to take advantage of S&T, especially high-tech, such as nanotechnology. Since the 21st century, the investment in nanotechnology has increased dramatically in China and the number of researchers and publications in nanotechnology and nanoscience has reached to the top level of the world, and nanotechnology-related enterprises and products have leaped too.

It is well-known that high-tech is a field of high-investment, high-benefit as well as high-risk. There are abundance evidences revealing that nano-products may be great risky to human health, social safety, and eco-environment. Especially, as a developing country, China's ecological environment is fragile, populace is dense, health care system is yet to be perfected, and fund and governing experience are insufficient. To treat with those risks, it is necessary to appeal to the social responsibilities of scientists and engineers, but also co-efforts from all circles including government, enterprises, researches and the public (Renn and Roco, 2006), since the development and application of the magnitude S&T do neither rely on scientists and engineers only, nor just impact on them.

While high-tech is promoted for boosting economic growth, the social governance is necessary for the development of such risky technology. There are many studies and activities on nanotechnology risk governance in Europe and the US which deserve attention and advocacy (Roco et al., 2008; Macnaghten et al., 2005; Swierstra and Rip, 2007).

By analyzing the official documents ("National Nanotechnology Development (2001-2010)" and "Long-term Scientific and Technological Development Plan") and papers published by National Nanotechnology chief scientist and others, the author found that the possible risks and negative effects of nanotechnology extremely rare access to the vision of Chinese government and scientists, and there is still a long way to go for nanotechnology governance.

The author reviewed the social context in China from the aspects of Chinese cultural tradition, mainstream ideology, and social system etc., and addressed the barriers of nanotechnology governance as follows.

1. Under Deng Xiao Ping 's slogan of "Development is the last word", economic benefits out of the development of S&T are attached much more importance than environment protection. 2. Scientism and instrumentalism still prevail. Many people believe that social problems can be resolved by the progress of S&T only, and neglect or push aside cultural education and humanities and social science which couldn't bring economic benefits directly. 3. High centralized and paternalistic government is accustomed to make policies depending on the will of the enlightened leadership, which lacks openness and transparency, and it likes to launch mass movement as "a gust of wind" rather than set up normative and sustainable systems. 4. The public are used to be obedient

people, and are lack of citizenship with right and responsibility. 5. There are lack of institutional access, such as intermediaries, social organizations and NGO, to deliver public opinions, etc.

The author argued that those barriers should be overcome, in order to implement the nanotechnology governance. Some suggestions on policy-making were provided in this paper. For instance, strengthen strategic guidance and nanotechnology assessment; appropriation special funding to study the social and environmental impacts when developing new nanotechnology products, and those interdisciplinary studies should not only be done by scientists and engineers, but also have experts from humanities studies and the public involved; popularization of knowledge of nanotech and its possible positive and negative social effect; The author calls for people from different areas actively communicate and exchange opinions, and share the responsibilities of reasonable application of nanotechnology.

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On the Feasibility of the Nanotechnology

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As early as 1959, Feynman(Feynman, 1959), a physicist, predicted that nanotechnology can bring new forces, new effects and new possibilities. Today, the fast development of nanotechnologies has demonstrated their tremendous possibilities. Some of these possibilities have converted or are converting into enormous economic and social benefits, which make our life much more convenient, comfortable and beautiful, and at the same time worry people because of the uncertainty and negativity of their effects. Therefore, people start to question the possibility and feasibility of nanotechnologies, to rethink whether what is possible should be feasible.

At the beginning of this report, the possibility of nanotechnology of the contemporary era is described. Then the nanotechnology is discussed as an enabling technology (Roco and Brainbridge,2003) by focusing on the main character of nanotechnology—possibility. So the author starts from philosophic reflection on the concept of possibility, analyzing the inherent relationship between possibility and feasibility, and hence the necessity of feasibility analysis.

The second part of this report is to investigate the connotation of the current concept of feasibility. As an important concept in the fields of economics and management, the current definition of feasibility has its limitations in that only the rationality and purpose of measures are investigated while the feasibility and rationality analysis of the purpose of the action are ignored. For that reason, the Chinese concept of feasibility is introduced. Feasibility is called Ke Xing Xing. In Chinese, Xing has many meanings, for example, going, action, doing, behaviour, advance, activity and etc. But the first meaning is going (Han Dian, 2006). The word is comprised of man and crossing. In order to pass the way, to advance, he has to choose the way. Therefore one has to think which way to choose before going. The word 'way' here is beyond just road. It is also a philosophical term and conveys meaning of principle, ideal and method. The author believes that the concept of the feasibility in Chinese philosophy can enrich the connotation of the western concept of feasibility. Therefore, the most important during the investigation of the feasibility is to look into the feasibility of purpose. The third part of this report begins with verification that the feasibility concept lies between possibility and reality. It is pointed out that the concept of feasibility is concrete and individual, which is related to certain purposes and measures. This character determines that the feasibility can vary with individual person, event and situation. Therefore the strategy to verify the feasibility should be individual, situation and time oriented. When it comes to the feasibility of nanotechnologies, the author believes that one must regard the analysis of feasibility of nanotechnologies with the attitude of real time, real space and being dynamic. What is very important is that individual has the right to make decision whether he needs this technology, because he has to bear the consequence and impact of nanotechnology. Therefore the feasibility of nanotechnology should follow the following points during decision-making: 1) public participation; 2) regulated decision-making; 3) amendable purpose; 4) normalized standard.

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Contextualize Engineering in the Culture of Dao

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Numerous STS studies have demonstrated that engineering practices exist in socio-cultural contexts, and different cultural traditions influence the economic and social welfare results of engineering activities. (Christensen et al, 2009) Dao, as a unique idea in Chinese philosophy, has been shaping the developmental trajectory of Chinese cultural history and is seen as the way of natural and social processes, which can include technical and construction activities. (Wang, 2006) This paper aims to understand engineering and its pre-modern form (here uses gongcheng to refer the premodern form of engineering) in the cultural context of dao, identify the cultural characteristics in contemporary engineering industries by using a dao ji (means) interpretive framework and proposing policies for responding to social-engineered problems by recognizing the values of dao.

First, this study examines that how dao as an ideal shaped gongcheng and related practical ethics by generally reviewing the cultural-philosophical history of gongcheng. Though gongcheng differs from engineering which bases on the modern science, the cultural analysis will be valuable for identifying the modern socio-engineered problems which partly root in historico-cultural impacts. Unlike the common philosophical understanding of dao which centers on its role in the becoming and perishing of things, it offers an interpretation from the perspective of engineering. Based on Joseph Needham's archaeological contributions, it argues that the initial meaning of dao emphasized its function as a process which enabled people to walk from one place to another, guiding them step by step, rather than burdening their minds with the structure of the way as permanent reality. Pragmatically, dao refers to an ideal or optimum way to move (not just geographically but also historically) from one point to another. (Wang, 2009) In this sense, dao serves as an ideal model for gongcheng which also indicated the optimum procedures for designing, implementing, and operating — that is, the harmonious (the core understanding of the good in Chinese philosophy) way to construct artifacts. The idea of a "harmonious" gongcheng can be mainly unpacked into four types: (1) harmony with the natural environment; (2) harmony with social realities; (3) harmony between practitioners and stakeholders; and (4) harmony among operators, instruments, and objectives. (Wang, 2009) A deep appreciation of dao in gongcheng leads to a practical ethics (as diverse as wu le gong ming and yi she) influenced and developed by such a thoughtful ideal. Additionally, this approach argues against a Euro-centric activity was devoid of any ethical guidelines and that there is not engineering ethics indigenous to Chinese cultural history.

Second, this study argues that the transition from gongcheng to engineering in the modern sense occurred as part of a dialogue between traditionalism and modernism. Since engineering was imported into China during the Westernization Movement, along with the dominative logico-analytic methodologies that rejected the holistic and organic ways of thinking, the split between traditionalism and modernism undermined regulation by the culture of dao. Such a loss, together with the limitations of the ethos of the liberal economic order based in equality and fairness, left the idea of dao unable to address modern requirements for responsible innovations. Because the governing system of dao was designed solely for gongcheng, it could not be fully adapted to the modern situation. All these factors stimulated the emergence of cultural phenomena in engineering called the "divorce between dao and shu (technique or means) (dao shu fenjia)", which means that engineering practices have been pursed outside the influences of dao and have lost their foundations in moral regulations. The inefficient function of engineering ethics in China partly comes from the confused complexity of moral systems rather than Chinese failures to learn western engineering ethics.

Finally, this paper suggests that policy proposals to address social-engineered problems can be dao based rethinking of the transformative characteristics of engineering. Such an initiative would aim to construct a new cultural context of dao in which engineers, engineering, and institutions could be cultivated with Chinese characteristics and respond to the requirements of an engineered society. In reflection to engineering practices, this paper makes recommendations to contribute the construction of new order that: (1) understand the mechanisms that by which engineering practices alienate from dao, and form the cultural analyses of socio-engineered issues; (2) develop engineering as a profession by integrating Chinese characteristics rather than completely adopting western philosophies and regulations; and (3) appreciate the ideal of harmonious engineering from the perspective of dao in light of the communities' needs and consider what is the "appropriate engineering" for Chinese needs rather than modernizing cities just as copies of New York.

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Tick Your Race: Hawaiian Native, American Indian, Other Pacific Islander, Alaska Native, Black or African American, White, Asian or Cyborg

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Up to now, coexistence between mankind and biorobotics is limited to the futuristic scenarios depicted by science fiction. Our current machines are far beyond their imaginary mates and if your robot floor cleaner manages to superficially clean half of your apartment without damaging any furniture, you can consider yourself extremely lucky.

However, we cannot disregard that interaction between humans and machines is getting more complex. Everyday technology goes one step further: while five decades ago we were focused on building robotic arms for our factories, now we look forward to developing androids that will replace our soldiers in wars or will be able to take care of children and the elderly. This evolution will lead to a world where machines will leave their place inside the cupboard to find a seat at our tables, a world where robots will acquire their own social status and will be ready to cry out for "Liberté, Egalité, Fraternité".

The purpose of this paper is to discuss the advent of a new race and how to face such a social disruption.

New Race

Historically, robots have been designed to perform repetitive and tedious tasks. To this end, sequences of instructions following some rules embedded in sophisticated hardware have sufficed to reach accurate results. Is this the new race that we are talking about? No. Nobody expects that mechanical arms will unleash the revolution. The concern arises with the coming generation of robots designed to do tasks with a high degree of human interaction and decision-making ability, such as fighting or nursing. On the one hand, human appearance, expressiveness, and emotions in robotics are necessary to make such interaction easier. On the other hand, morality, consciousness, and common sense are key components to replicate the decision-making mechanism of humans.

Thus, philosophers and engineers should combine their efforts to foresee the social and legal challenges that the creation of autonomous moral agents may entail, challenges that are not unfamiliar to mankind.

Liberté. If we create autonomous machines with human traits by means of evolving systems that allow them to reason, make their own decisions, and elaborate their own theories beyond the control of the designers, we are granting them liberty.

Fraternité. If we trust them to take care of our loved ones or think about them as roommates, we are granting them fraternity.

…galité. Once machines realize that we have given them freedom and esteem, their electric brain will rapidly produce the following question: is there any reason to be treated differently from humans?

Equality entails the admission of a new race. A race that will be eager to find a place in our society, just as every other race has done before.

Face a Social Disruption

Mankind has not been very skillful when it comes to social integration. Throughout our history, humans have continuously classified themselves according to their race for social purposes. We have used the race factor to discriminate against those who are different or weaker, and robots should not be an exception.

Thus, we should use what we have learned from the past and draw up a plan to face the social challenges ahead. This plan should be focused on (1) Education and (2) Law.

Education. We take for granted that, at first, robots will rank below humans and animals. This position, however, will not last because robots' skills will rapidly expose such a social nonsense. Therefore, we have to teach ourselves how to assimilate the arrival of a new race that has the strength to call into question its social status.

Law. New regulations will be required. If a robot injures a person (or another robot) by malfunctioning, who is responsible? The designer? The owner? The robot itself? Is the robot entitled to own things? To the extent we follow "Liberté, Egalité, Fraternité", robots cannot be treated as products anymore. Their consciousness confers, at least, the condition of quasi-person like children. Hence, the Law has to address their legal status.

Education and Law should provide the basis for an initial coexistence. The final social role of machines, however, is far from being clear. Although we can easily imagine that the robot floor cleaner's main aspiration will be limited to having full charged batteries, we cannot envisage the expectations of a cyborg once it realizes that its abilities are far more powerful than those of the human trying to make it understand that his/her/its race is not allowed to dream.

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Creating Interdisciplinary Forums in Philosophy of Technology at UPRM

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The Philosophy of Technology is a growing field worldwide (Papadopoulos & Hable, 2009; McGrann, 2008). However, the subject is not always visible to students and faculty, particularly in Engineering. In response, the Interdisciplinary Group of Philosophy, Engineering and Technology was created at the University of Puerto Rico in Mayagüez (UPRM). The Group consists principally of three faculty members from diverse academic areas, and organizes a series of forums and small round table dialogues called tertulias to explore philosophical questions related to engineering, technology, and innovation. These events combine presentations and audience discussion, and are moderated to encourage broad participation and sharing diverse ideas. The result has been engaging debates and strong exchanges of perspectives.

The Interdisciplinary Group provides space and opportunity at UPRM for the critical discussion of technology and its social implications, and has the following objectives: (1) establish and strengthen liaisons among the professoriate and student body, particularly across the disciplines of philosophy and engineering; (2) expose the university community to the cultural, ethical and political issues related to philosophy of technology in general, and also related to use and development of technology at the university; (3) expose engineers to the ethical issues of technology that extend beyond traditional "micro"-ethical norms and professional standards; and (4) promote the inclusion of social responsibility and development of appropriate technology as a fundamental part of engineering (Castro-Sitiriche, 2010a).

The format of the forums includes student presentations followed by faculty presentations, followed by a question and answer session. Three forums have so far taken place and generated great turnout (40 attendees each) and a positive response from students and faculty was reflected in short questionnaires. The first forum, titled Connection and Concentration in the Classroom tackled the complex issues that the apparently simple introduction of the cell phone brings to the university classroom and other gathering places. The second forum, titled Ethical and Philosophical Questions About War Technologies, focused on identifying ethical questions that emerge from the design of such technologies and distinguishing these from broader political and cultural questions. A third forum focused on Technology and Women.

The tertulia is a roundtable discussion in which the topic is established by the organizers and/or participants one-two weeks in advance. In some cases, short readings are distributed several days beforehand and provide the basis for discussion, while in other cases a brief presentation at the beginning of the tertulia introduces the topic. The first tertulia took place October 2009 and was titled: Engineering as an Enterprise of War and Peace. This activity was facilitated by one of the Group members who wrote a chapter by this same title in the book Engineering in Context

(Papadopoulos & Hable, 2009). During Spring 2010, tertulias on a variety of topics are offered about every 2-3 weeks.

The activities and objectives of the Interdisciplinary Group are included as part of the Social, Ethical and Global Issues (SEGI) in Engineering initiative, sponsored by the College of Engineering (Papadopoulos et al., 2009; O'Neill-Carrillo, 2008). SEGI sponsors faculty development workshops, courses, and modules pertaining to ethical, social, and global issues in engineering. Group members are directly engaged in the development, delivery, and assessment of SEGI activities.

Currently, modules are offered in a portal Freshman engineering class and in the Senior capstone design courses, while new modules for Sophomores are under development. An undergraduate course on Philosophy of Technology (Huyke, 2009) is offered every second semester through the Humanities Department and a graduate course based on SEGI (O'Neill-Carrillo, 2010) will be offered as a special topic in Electrical Engineering in 2011. Furthermore, a new interdisciplinary undergraduate course in Appropriate Technology is being developed for Spring 2011.

In conjunction with ongoing ABET assessment activities, the various assessment instruments are employed to evaluate the outcomes of the SEGI activities. Within this overall effort, the Interdisciplinary Group assesses the outcomes of the forums and workshops by tracking attendance and conducting feedback questionnaires after each event. Additional assessment measures are under development. To further document and disseminate Group activities and outcomes, a blog is maintained by one of the Group members (Castro-Sitiriche, 2010b).

The Interdisciplinary Group is led by three faculty members from diverse backgrounds and affiliations. These include the Department of Electrical and Computer Engineering, the General Engineering Department, and the Humanities Department. Their affiliations collectively include the Society for Philosophy and Technology, the Society on Social Implications of Technology from the IEEE, the American Society for Engineering Education/Ethics Division, and the Association for Practical and Professional Ethics. Interdisciplinary perspectives in the critical analysis of technology are essential in any meaningful reassessment of the direction of humanity in the context of a culture immersed in technology. The paper provides an example of such an interdisciplinary approach in a university setting.

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Integrating Philosophy into the Education of Engineers: Some results from the UK

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Over recent years discussions with an explicit focus to expound the philosophy of engineering have resulted in a rich output of ideas and material. For educators of engineers, the integration of the more philosophical outputs into teaching regimes remains a challenge and this paper charts some of the efforts being made in the UK towards this end. Specifically, the paper draws on the output of a discussion forum that aimed to uncover practitioner perspectives on engineering and philosophy (ICE 2005). These perspectives were then analysed at a workshop where a roadmap was created to engage philosophical principles with the educational curriculum of engineers (HEA 2006). Fours years have now passed since the workshop and the production of the roadmap, so it would be useful to reflect on what progress has been achieved

The idea of a philosophy related to the theory and practice of engineering is no longer a new, but it may still be described as in its infancy when related to disciplines with a longer philosophical tradition (Mitcham 2008). The weakness in the philosophy of engineering is exemplified by the lack of published literature outside of the few events such as the two Workshops on Philosophy & Engineering to which this event serves as part of the continuum.

The discussion upon which this paper is based was established with the good will of the Institution of Civil Engineers (ICE) and had the aim of encouraging a debate to consider the question “Where is the philosophy in Engineering?”. The discussions ran for a period spanning approximately one year and attracted 40 regular contributors. From the forum came a wealth of knowledge, experience and philosophical reflection on many important concepts that underpin the engineering profession (Fox 2006).

In addition, a workshop was hosted by the Engineering Subject Centre of the Higher Education Academy (HEA), and was supported by the Centre of Excellence for Teaching and Learning (CETL) for Ethics at Leeds University and the Philosophy and religious Studies Subject Centre of the HEA.

The rationale that instigated the original discussions has not changed, which was essentially that, like all other professions, the body of knowledge that constitutes the sphere of engineering continues to grow. As a result, the education of engineers is forced to focus on increasingly specialised areas of knowledge with the threat that the greater meaning of engineering is lost.

The philosophical discussions that have ensued following the start of this project have served to reiterate that professional engineers consider their profession to be centred about doing. Engineers take materials from the world about them and reshape them for the betterment of mankind. This requires a conscious effort and the application of logical thought to satisfy a perceived need. As a logical process, engineering involves the formulation of concepts, the design of solutions and the creation of physical manifestations of those solutions. It utilises resources that may be inert, semi automated or even living and it is driven by an instinct for survival, a need for protection and desire to develop.

A broader philosophical understanding of the subject area reveals that engineering is not free to be applied at will to any perceived need, but must work within cultural constraints and adhere to the moral and ethical standards of the society in whose service it is employed. Not withstanding such limitations, its proponents do aspire to achieve the both artful and efficient utilisation of resources and the attainment of ultimate truth in the solutions derived from their efforts.

In essence, to grasp the greater meaning of engineering requires the development of philosophical concepts such as a cognitive awareness of life, self, others and the external world. This needs to be blended with a higher understanding of science, the environment and society. And, as servants for society engineers, through their education, should acquire knowledge of a sense of duty, sentiment and humility. Engineering is therefore not just about mathematics, design, experimentation and manufacture; it is about epistemology, ethics and metaphysics. If engineers desire to truly understand themselves, their profession and their role in society, they need to include in their education the study of philosophy.

This philosophy seems to centre upon “doing”. Doing, to meet the needs of society, but also doing with invention and throught the use of technology. This suggests that engineering is deeply rooted in human actions and the author has struggled to find the point where engineering separates from mankind’s conscious awareness of their actions. Engineering seems to be a fundamental process in humans, encompassing the drive toward satifying their every need and which may have started the instant they became conscious individuals. It could be argued that to “engineer” is second only only to conscious awareness, and has lead the author to end this paper with a question:

Cogito ergo sum! Facio ergo ingeniare?

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Engineering Engagement: Practice, Theory and Reflection on Being an Engineer and Being Human

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Engineering Engagement is a collaborative project between three engineers – a graduate, an academic and a practicing consultant. It aims to investigate the active engagement of the engineer, the business and the profession in reflecting and acting on the influence of the personal, social and political elements of engineering practice. This paper has two aims:

1. To capture the personal narratives behind our identification of the Engineering Engagement agenda; and
2. To reflect on how this interdisciplinary task has been informed by existing literature from the philosophy and social studies of technology and engineering, and to highlight opportunities for further theoretical development to better inform engagement between engineering practice and social and political values.

Sharing a background in Environmental Engineering, our individual experiences led us to believe that the engineering practice cannot be detached from values and politics. In our experience conventional accounts of engineering as objectively detached from personal, social and political values are inadequate and undermine critical engagement with the nature and implications of engineering practice. Our eclectic work histories and interests are shaped by our personal values, our engagement with public and institutional politics as well as our formal training and professional development as engineers. None of these can be easily delimited from the other.

The Engineering Engagement project focuses on the international design and engineering consultancy firm, Arup. The concept of Total Design, developed by the firm's founder Ove Arup, as well as his approach of encouraging his firm and the wider profession to continually reflect on their role and moral aims within the larger and continually changing societal context attempted to shift the conventional view of engineering practice towards more holistic and inclusive approaches. Research conducted thus far has produced a historical analysis of the role of Ove Arup's design philosophy in the development of the firm (Chilvers, 2009). Ongoing work is developing this with a critical account of how the firm engaged for the first time with public politics to challenge a prevailing view on a major piece of transport infrastructure. A real-time ethnographic study of the Arup practice is also underway aimed at empirical data collection on the attitudes towards and processes for critical reflection within Arup as well as the opportunities and constraints on this in consultancy practice. Ultimately the aim is to develop the Engineering Engagement concept and assess its validity in explaining how engineers work at Arup and Arup's capacity to respond to current and future global challenges.

Review and synthesis of existing approaches to the philosophy and social studies of engineering has been an important foundation for the project. Diverse contributions including actor-network theory, the social construction of technology, value centred design and the philosophy of technology provide important methodological grounding for the empirical studies of Arup's history and practice, and allow for critical analysis of our findings and experience (for example Bucciarelli, 1994; Bijker, 1995; Friedman and Kahn, 2003; Latour, 2005, Mitcham, 1994). The practical and empirical focus of the project requires a pragmatic approach when dealing with the contradictions and disagreements between the different theoretical perspectives, and highlights opportunities for further theoretical developments to better support engineering engagement in practice.

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Philosophy of Structural Building Codes

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The authority of building codes is granted by a common appeal to public safety. These codes are identified as minimum standards to safeguard the health, safety, property, and welfare of the public, which seems like a reasonable foundation upon which to build a set of regulations or to formulate a philosophy of how the public can best be served and protected. These codes contain both explicit and implicit directives that identify minimum standards of building performance that engineers and architects must comply with in structural design. An example of an explicit requirement is that an anchorage of a concrete wall to a roof diaphragm must be able to carry 200 pounds per linear foot (plf) for allowable stress design under seismic load combinations (ICC 2006, Section 1604.8.2). An example of an implicit criterion (ICC 2006, Section 1604.4) is that structural systems must provide a complete load path capable of transferring all loads from their point of origin to the load-resisting elements (e.g., shear walls and footings).

Explicit and implicit requirements are necessary to meet the overall goal of safety. Building officials charged with enforcing these regulations often do not possess adequate training to interpret the appropriate response to an implicit code requirement, whereas they are perfectly suited to enforce explicit directives. Implicit requirements permit a range of solutions based on the engineer's experience and creativity, whereas explicit instructions allow no leeway. For example, if a minimum anchorage force of 200 plf is required, then 190 plf is insufficient and would be in violation of the building code. The implicit requirement for a complete load path, however, would allow an engineer to design a system based on actual loads (possibly less than 200 plf) and select components that are better suited for smaller loads, yet retain the characteristics of ductility so important in seismic design. The engineer is thus allowed broader latitude with which to judge the performance of a specific structure.

Over the years, codes have become more explicit, and implicit instructions are being overshadowed. Granted, implicit directives are more difficult to enforce, but a greater amount of explicit requirements does not necessarily lead to safer structures. It is often difficult to decide how heavily to weigh the importance of these two elements (Shapiro, 1997; Coeckelbergh, 2006). If building codes are too explicit, innovation can be hampered and engineers may be viewed as simply instruction-following technicians (Coeckelbergh, 2006). If they are too implicit, then proper enforcement of construction requirements for safe structures can be difficult to perform and the likelihood of a structural failure may be increased (Elms, 1999). Many engineers argue that modern building codes do not adequately achieve a balance, typically tilting too far in the direction of prescription, as the ever-increasing thickness of the printed code documents suggests (Hess, 2009). The intent of the code often gets lost as it grows in size, and provisions that were simple at one time become more complicated, which reduces the effectiveness of the code and stifles innovation and creativity on the part of responsible designers. Codes that are too complicated (often overly explicit) make it difficult for a designer to know how many of the requirements must be met to justify a specific design; and codes that are too simple (overly implicit) do the same thing except in that case the question is what should be used that is not specified to justify the design (Addis 1990)

Perhaps there is a better way to blend explicit requirements with implicit provisions so that codes do not become increasingly burdensome and yet the intent is clear enough to permit innovative approaches to solving structural engineering problems. An approach to future code updates that might serve society and the engineering profession better would expand on implicit directions in the code and include a commentary that gives suggestions to an engineer for achieving the stated goals. For instance, the code could consist of a specification that is mostly implicit, a commentary that gives suggestions about how the specification could be met, and a supplement that includes aids for designs done in accordance with the commentary methods. The specification could be written such that use of the commentary techniques would lead to a deemed-to-comply design.

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The Case for the Inclusion of a Lay Person or Persons on Engineering Accreditation Panels

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Over 100 years ago George Bernard Shaw (1913) claimed that the professions are conspiracies against the laity and today we are living in an age when the role and behaviour of professionals are being questioned as never before. Taking a broad definition of the professions to include, amongst others, law, medicine, economics, politics, accountancy, finance, science, architecture and engineering, it is evident that most are under one form of scrutiny or another with significant ethical questions being asked. Consequently, a philosophy of engineering, however difficult it is to formulate, must include in its scope ethics as well as the other main branches of philosophy. Further, if this philosophy is to have real impact and meaning it should permeate the education and formation of engineering professionals. The focus of this paper is on how the professional bodies assess the effectiveness of the ethics curriculum within undergraduate engineering education.

It has been argued, perhaps most clearly by the philosopher Carl Mitcham (2008), that engineering as a profession is philosophically weak, with one basis for this argument being the profession's approach and attitude towards ethical behaviour. This can be further compounded when engineers belong to other social groups with opposing ethical positions. The substance of this argument was highlighted by Robert Veatch (2009) in relation to medicine, but many of the arguments are applicable to other professions. Christelle Didier (2009) has also written about the challenge of resolving opposing ethical demands with specific reference to engineering and concluded that 'engineer's positions are inextricably linked to their religious adherence'.

The central question can be posed as follows: have the non-technical societal and ethical aspects of engineering been adequately addressed in the accreditation criteria for the formation of professional engineers? The educational standard required of engineering programmes is the result of coordinated processes that represent best practices as interpreted by academics, with relevant input from professional bodies, taking heed of the demands of industry and society, and resulting in accreditation criteria. In this respect the Accreditation Board for Engineering and Technology (ABET) has taken the lead role in developing and implementing accreditation criteria for engineering programmes within the United States and the European Network for Accreditation of Engineering Education (ENAEE) acts similarly as an umbrella organisation within Europe. Whilst the accreditation formulations differ, the corresponding criteria are essentially equivalent.

To illustrate our position, consider the accreditation criteria established by Engineers Ireland (2007). The learning outcomes described within these accreditation criteria state that engineering graduates must be able to demonstrate inter alia: (i) an understanding of the need for high ethical standards in the practice of engineering, including the responsibilities of the engineering profession towards people and the environment; and (ii) the ability to communicate effectively with the engineering community and with society at large. One immediate question arises: what constitutes high ethical standards, and consequently how would an engineer know that their practice is ethical and of a high standard? Another question centres on the assessment of whether the learning outcomes in question have been met within the programmes being accredited. And finally, who is charged with judging the degree of compliance?

The answer, briefly, is that the process is one of internal regulation with engineers acting as legislator, judge and jury in evaluating engineering programmes. While many in engineering circles see no difficulty with this, the system offers little or no guarantee to society that criteria (i) and (ii) above have been adequately addressed and assessed. To express the point colloquially, is the 'gene pool' for both the writing of the accreditation criteria as well as the assessment of whether engineering programmes meet those accreditation criteria too narrow? While some might argue that 'if it ain't broke, don't fix it', evidence to the contrary is provided by Sheri Sheppard (2008) showing that the practice of engineering, and therefore the educational requirements for the development of engineers, has fundamentally changed.

Proposed solutions: first, accreditation bodies such as Engineers Ireland should involve experts in ethics to help articulate and describe what constitutes a high ethical standard; second, examples of good practice in addressing ethical and societal issues in engineering programmes should be collected and made available to those devising curricula; third, accreditation panels should include one or more independent non-engineers knowledgeable in ethical matters to assess whether the relevant criteria have been met. The philosopher Onora O'Neill in her BBC Reith Lecture (2002) claimed that trust is the pre-eminent attribute required of those in authority: what better way is there for the engineering profession to ensure that there is mutual trust with society than by allowing within its accreditation structure appropriately skilled laypersons to act as a moderating influence in ethical matters.

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Ethical Relations and Engineering

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Ethical Relations and Engineering

Abstract: Suppose Robinson Crusoe had been a civil engineer. He would not need to concern himself with holding "paramount the safety, health and welfare of the public." No one else was on the island. So he also could never be a faithful, or an unfaithful, agent. He could have no conflicts of interest, ignore the profession and other engineers, forget about "bribery, fraud, and corruption." Because he was by himself, nothing in the engineering code of ethics would apply to him.

The code assumes that an engineer works in a social setting and that ethical issues arise only in relation to others – employees, clients, other engineers, the public, and so on. Going hand-and-hand with this first assumption is a second about the quantitative purity of engineering. In the Preface to Essentials of Engineering Design, to cite a typical remark, Joseph Walton says that the last of the ten chapters "raises ethical questions that an engineer may face from time to time, the non-mathematical problems that need more than a calculator to answer" (Walton, xv). Engineers face problems to be solved by using calculators while ethics poses "non-mathematical problems" for which calculators are useless. Engineering is quantitative; ethics is not. On this view, ethical issues can only arise when an engineer takes on a relation to someone else – the public, for instance, or an employer – because ethics is not integral to engineering practice. If it were, engineering's quantitative purity would be muddied by qualitative matters.

These two assumptions are false. Even by himself, with no one else around, with no client, no employer, no public, Robinson Crusoe could have acted unethically as an engineer – in two different ways.

First, he could have calculated improperly, skewing his fort, or he could have chosen the wrong materials, building a structure that would not weather well. He would then have failed to satisfy some demands of the role-morality internal to engineering. Such demands are neither trivial nor unusual. They define a profession's ethical core. Physicians are not to cure their patients by sending them to a smoke house. Surgeons are not to operate while imagining themselves slicing and dicing their imaginary opponents as they cut into your organs. Professionals who act in such ways fail the ethical principles built into their professional roles. It does not matter ethically what their intentions, and whether they harm others or not is a separate ethical issue.

Second, the intellectual core of engineering is solving design problems of a certain sort, and in determining how to build his fort, Robinson Crusoe was necessarily making value judgments in fashioning and choosing his design solution. Engineers always do this. Sometimes cost is of more value than aesthetic appeal; sometimes effectiveness wins over cost; sometimes reliability wins over ease of manufacture. Whatever choices are made among the various values and whatever our criteria of choice, hovering above is a moral principle that ought to animate every choice: do no unnecessary harm. That is an ethical principle, internal to engineering, that holds regardless of what an engineer may intend, and the harm need not be to others. The worst possible design solution would be what I call error-provocative, so faulty that it provokes errors even in the most intelligent, best-trained, and highly motivated users, including the engineer, Robinson Crusoe, for instance, who chose the solution.

The code of ethics captures, to some extent, the ethical issues that arise because an engineer is acting as something else – a agent, a citizen, an employee, a manager, say. These are external to engineering itself, and Robinson Crusoe can ignore them. What he cannot ignore are those ethical issues that are internal to the profession, embodied in its role-morality and its intellectual core.

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