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THE PRACTICAL SIDE OF ENGINEERING DESIGN

Winkelman, Paul Martin
The University of British Columbia, Canada

Abstract

In the minds of many, including engineers themselves, engineers are considered to be “practical”. But what is “practical” and what values does it promote? Building on a simple search in engineering design literature, “practical” is shown to represent five values: ethical (consideration of needs and a call to action), non-cognitive (knowledge which is difficult to articulate), real (vs contrived, such as the world of education), deliberation (stressing the importance of context and the difficulty of choosing the best solution) and alignment (seeking a short, direct pathway from problem to solution based on what has gone before). The problem with alignment is that it necessarily leaves things out and, if politics and history are left out, engineers will likely find themselves working on projects in keeping with historical trends and dominant political values. And these values may not coincide with their own.

Keywords: Design practice, Social responsibility, Education, Engineering discourse, Engineering values

Contact:
Dr. Paul Martin Winkelman
The University of British Columbia
Mechanical Engineering
Canada
pwinkel@mech.ubc.ca

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1 INTRODUCTION

"The engineer is a practical man" (Hertsgaard, 1983, p. 180).

Gender bias aside, this statement perhaps captures the sentiment of many engineers who take pride in seeing their work as being oriented towards the "practical". Hertsgaard here is quoting a top manager in a nuclear power company presumably speaking on behalf of the engineers working under him. He goes on to describe how the "practical" is manifested in the engineer: "He is resigned to using science for the betterment of mankind. And he's used to making trade-offs. Cost-benefits are put in front of him from day one of engineering school – if you do this, you'll get that, is it worth it?".

Within engineering circles, as in the case of the manager above, the word "practical" is generally presented in favourable terms. It hints of positive values embedded in the engineering enterprise. However, is the word "practical" as used in engineering necessarily praiseworthy? Might its use, at times, undermine the very values we seek to promote? In seeking and being guided by the "practical", might the engineer be headed in the "wrong" direction?

2 PURPOSE

The purpose of this research is to explore the values within engineering and how they are manifested in engineering discourse, education and (design) practice. The more specific objective at hand is to explore how the word "practical" is used within engineering discourse and the values its use seeks to promote. One of issues is that, as the meanings of words tend to be rather "slippery", subtly shifting definitions can produce subtly shifting values and engineers risk finding themselves engaged in the "practical" which is not in keeping with their values.

3 APPROACH

To gain an understanding of how the term "practical" is used in engineering and to determine the values promoted, a series of excerpts was selected from design literature (largely, but not exclusively, engineering design). Engineering design journals constituted the primary source and these were searched for the term "practical". Additional excerpts were gleaned from books on hand or from more casual readings where the use of the word in engineering contexts caught my attention. Loosely defined, this initial list constitutes the "raw data".

The "raw data" is then analyzed in two stages. In the first stage, these excerpts are arranged according to the nouns that "practical", used as an adjective, modifies. Repetitive excerpts are put aside to limit the size of the list. In the second stage, these "practical" excerpts are interpreted and re-classified from the perspective of engineering values. Additional literature is cited to support or counter the claim or, at least, muddy the waters. This classification is carried out in full knowledge that such schemes are always problematic as there will always be outliers, given a large enough number of elements to classify. Thus, not all of the excerpts will find their way into the new classification scheme. This two-stage approach of this initial investigation allows for a relatively clean presentation; subsequent studies will directly classify the "raw data" into categories based on values.

4 "PRACTICAL" AS MODIFIER

In the first stage, a total of 32 excerpts were placed in 20 "noun" categories. To limit the number of categories in this list, I've taken the liberty of grouping some nouns together whose meanings I believe are quite similar. I've also taken a few liberties in associating a particular noun with "practical" when the noun is a bit distant from its modifier. The excerpts are kept as short as possible, but long enough to provide sufficient context as to the intended meaning of "practical" by the author(s). Some additional context is provided in later discussions.

- **Person**
  - as noted above
  - "The course really helped develop a student's sense of structural behaviour, which is a key element to being a practical engineer" (Hutchins, 2015).
- **Application, implementation**
  - "What are the practical applications of virtual reality?" (NAE, 2008, p. 43)

- “The two major areas that can contribute to the successful practical implementation of this approach include improving the search efficiency and reducing the execution time” (Carlson-Skalak, et al., 1998, p. 80).

- **Implication, consequences**
  - “Our analysis informs a theoretical understanding ... whilst also having practical implications” (Christiansen, 2016, p. 132).
  - “While the theoretical consequences of IIA are devastating, it is not clear that the same is true of its practical consequences” (Dym, et al., 2002, p. 236).
- **Value**
  - “Such computers, in addition to their possible practical value...” (NAE, 2008, p. 50).
- **Constraints**
  - “There are physical and practical constraints that include the locations of meetings...” (McDonnell, 2016, p. 12).
  - “These are not difficult requirements to meet, and indeed are typical of the kinds of practical constraints imposed on any real design problem” (Maier and Fadel, 2009a, p. 25).
- **Knowledge**, **information**
  - “... the expertise we are focussing on is a kind of knowledge that is practical...” (Heylighen, 2012, p. 102).
  - “The knowledge of engineering design has also been considered from several aspects, such as governmental, industrial, historical, technological, educational, scientific, sociological, and practical” (Horvath, 2004, pp. 155-156).
  - “... offers practical information about what to do” (McDonnell, 2016, p. 23)
- **Intelligence**
  - “Design intelligence ... has three appearance forms, namely: (1) synthetic, (2) analytic, and (3) practical” (Horvath, 2004, p. 162).
- **Guidelines**
  - “... studying mathematical models of design could produce practical guidelines or ideas for implementing design support procedures ...” (Braha and Reich, 2003, p. 186).
- **Decision**, **dilemma**
  - “... and simultaneously perform practical design decisions and ethical acts towards others.” (Oak, 2012, p. 644).
  - “The focus is on how participants manage a practical and moral dilemma:” (Oak, 2012, p. 644)
- **Format**
  - “... the information may be available to them in a ‘practical’ format that is hard to communicate to others...” (Heylighen, 2012, p. 103).
- **Evaluation**, **assessment**
  - “While these value dimensions may frequently be entangled with practical, creative evaluation...” (Christiansen, 2016, p. 118).
  - “But it makes their assessment a practical, not a cognitive task” (Heylighen, 2012, p. 98).
- **Experience**
  - “Practical experience suggests that the PCC generally preserves the original rankings if one alternative is dropped” (Dym, et al., 2002, p. 238).
  - “... we can only transfer the aspects that can be formalized in MCA [multidisciplinary combinatorial approach] and not the presently informalized practical experience that is rooted in context” (Shai and Reich, 2004, p. 105).
- **Skills**
  - “ ‘Recent [engineering] graduates are also often too reliant on computers, and need more of the practical skills they can only get from working.... That’s the kind of practical thing you don’t learn in a book’ ” (Hutchins, 2015).
- **Method**
  - “The effort in this paper is therefore to present a series of practical methods based on the theory of affordance-based design...” (Maier and Fadel, 2009b, p. 225)
  - “A practical method is to start from a relatively small population size and small number of generations...” (Xu et al., 2006, p. 37).

- **Training**
  - "Attempts to set up engineering schools offering practical training as opposed to 'education' were unsuccessful. If young people wanted practical training, they could get it on the job; they went to school for the prestige of an education, and vocational schools did not offer this (Beder, 1999, p. 14).
- **Process**
  - "Our mathematical framework should ... provide ideas for improving practical processes and insight regarding their outcome" (Braha and Reich, 2003, p. 186).
- **Action**
  - "… talk is a chief method through which participants demonstrate the practical actions and forms of mundane reasoning..." (Oak, 2012, p. 631).
- **Utility**
  - "The position that I developed above may have additional practical utility. It may offer a solution for two research issues in FB-to-FCO model conversions, currently investigated by Ookubo et al. (2007)" (van Eck, 2010, p. 109).
- **Project**
  - "Such [water] diversion projects provide some short-term relief for cities, but do not appear practical as widespread, long-term, ecologically sound solutions...." (NAE, 2008, p. 20).
- **Problem**
  - "The lack of theoretical coherency across the different sub-domains of Design Research is a practical problem" (Love, 2002, p. 347).
  - "In practical design problems, the solution space is openended" (Chong et al., 2009, p. 98).
  - "... enabling them to solve the practical design problem of transferring a disabled user to the sofa...." (Oak, 2012, p. 643).

5 PRACTICAL AS EMBODYING VALUES

In the second stage, these excerpts are re-classified according to the values embedded within them. I offer five different values which the use of "practical" appears to promote. Although other arrangements might be equally valid, I believe what I present is sufficient to show how "practical" refers to a wide range of sometimes conflicting ideals. Note that not all the excerpts are re-visited in this second classification.

5.1 Practical as Ethical

Oak (2012) speaks of a "practical and moral dilemma". This dilemma arises as students design a feature to allow a person to move from a wheelchair to a sofa. On the "practical" side, the students feel compelled to create a product that will work for a wide range of users; however, this more universal design may not meet the needs of the immediate client. The "practical" therefore suggests everyday activities, and the "everyday-ness" of the practical is reinforced as Oak speaks of "practical actions and forms of mundane reasoning". The "moral" side of the dilemma calls the designers to create a product which directly addresses the needs of the immediate client, presumably requiring design work which is not so "mundane". The idea of the "practical" as the mundane is echoed by Maier and Fadel (2009) when they state that "[t]hese are not difficult requirements to meet, and indeed are typical of the kinds of practical constraints imposed on any real design problem". Both "typical" and "any" speak of the ordinariness of the everyday design.

Oak (2012) does not equate the "practical" with the "moral"/"ethical" but rather maintains a separation. She does, however, mention the "specific needs of the couple" and reserves the term "needs" for the immediate client (the couple) only and not the generalized client of the universal design. Hence, there appears to be a strong connection between "needs" and the moral or ethical call.

Within engineering design, the term "needs" is not normally confined to the requirements of a narrow range of users, but is often applied on a larger scale. The very term "needs" implies a moral obligation, even when more universally applied, for to knowingly leave needs unmet when one has the power to meet those needs, is seen as unethical (sin of omission).

Hertsgaard (1983) expresses this same sentiment with the engineer as the "practical man" in the nuclear power industry. Hertsgaard refers to the "nuclear imperative" as seen in the eyes of the promoters of nuclear power and these promoters are waging a "holy war" that they are "destined to win" as theirs is the “moral and just cause”. The “practical engineer” has done the “cost-benefit” analysis and the trade-offs are clear: to forego what nuclear power has to offer is to risk the future, to deny the people their salvation. Yang (2009) echoes these same sentiments: “Behind the stubborn endorsement of nuclear power was moral determination. In nuclear proponents' minds, they were promoting nuclear power for the good of mankind”.

Being concerned with needs, engineers are called to act. Thus, the *Practical as Ethical* is a call to action. Indeed, the very word itself, “practical” is derived from the Greek word *praktikos*, meaning “concerned with action” (Oxford English Dictionary, 2006). Action is a common theme among many of the “practical” values and we shall return to this presently.

5.2 Practical as Real

In the first instance, the word “real” alludes to the physical reality, at least within traditional engineering. As engineering has also started to move into the virtual world, the notion of physical had to shift somewhat if engineers working in virtual reality are to be “practical”. Remembering that the engineer as “practical man ... is resigned to using science”, we can use science as a starting point as to what “real” might be. Being “resigned” to using science, engineers wish they could wave their magic wand and everything would be fine, but, alas, science precludes the possibility of miracles; science therefore forces engineers to stay within the bounds of the “real”. And science is brought in with all its trimmings, such as mathematics, logic and even rationality. For this reason, the “practical man” engineer “could not believe that any rational person in possession of all the relevant facts could sincerely be against nuclear power...” (Hertsgaard, 1983, p. 180).

As the “practical-man” engineer employs “cost-benefits” and “trade-offs”, economic models and theories, and basic accounting for that matter, speak of the “real”. There has been some shifting of the meaning of “cost” to include losses to, say, the natural environment, but the very use of the term suggests that to be “real”, one should not wander too far from the path set by the economic model. Thus, if a (dollar) figure can be assigned, it feels more “real”.

For some, “practical” and “real” means big. Nuclear power is big. Oil is big. Big is assumed to provide the benefits of economy of scale. Big means precision and efficiency. Smith (2013) presents the results of a survey where over 9000 U.S. undergraduate engineering students were asked about their “dream employer”. It would seem like they all wished to work for big companies/institutions, such as Google and NASA. To have a “real” job, an engineer must work for a large company.

For some, it would appear that the “real” is not defined by science, but one must go beyond science to experience the “real”. Chong et al. (2009) claim that “[i]n practical design problems, the solution space is openended” (p. 98). The “openendedness” here suggests a contrast to “closed” solutions usually associated with traditional science- and mathematics-based problems of engineering.

Chong et al.’s use of the word “practical” might also be interpreted as meaning “outside of educational or academic institutions”. Beder (1999) speaks of “practical training as opposed to ‘education”. This “practical training”, according to Beder, is obtained “on the job”. Hutchins (2015) mentions that “graduates … need more of the practical skills they can only get from working”. “Practical experience”, too, typically refers to that which takes place on the job in an industrial setting.

With the *Practical as Real*, engineers divide the world into two broad categories: the real (with all of its messiness) and the contrived. Education is very much seen as contrived, perhaps due to the (partial) protection it affords the students, keeping certain things out. What these “certain things” are is not immediately evident for the “practical”, too, is often concerned with keeping certain things out, as we shall soon see. For now, consider one engineering view of politics, in the context of discussing how “we” are to meet the challenges which lie ahead: “Engineers must also face formidable political obstacles” (NAE, 2008, p. 5). According to the experts, engineers should expect to be at loggerheads with political figures. Perhaps to be a “real” engineer, one cannot be sympathetic to political causes.

5.3 Practical as Non-Cognitive

In many instances, Heylighen and Bianchin (2012) makes a stark distinction between the practical and the cognitive: “But it makes their assessment a practical, not a cognitive task”. Speaking from the perspective of architecture, the practical/cognitive distinction arises in the discussion of whether inclusive design should necessarily be considered good design. Professional architects, who have developed the capacities and competencies to judge the quality of the design are said to do so cognitively, exhibiting a kind of objectivity. Those affected by the design but who lack the professional expertise, judge the quality of the design as an exercise of their freedom of choice, but this judgment is seen as a practical task as it cannot appeal to some objective fact. Thus, "inclusivity may be the norm, but it is a practical, not a cognitive norm". The "practical" here is not restricted to utility, as non-professionals can judge a design based on its aesthetic qualities. Using the car as an example, Heylighen and Bianchin point out that is not just about knowing the physical laws which impinge on car design, but also what makes a car "good", such as how fast or robust it is. "Practical" in this sense might therefore be used to describe the mode of judgment when one's relevant capacities and competencies are limited.

Heylighen and Bianchin (2012) also draw on the distinction of *knowing how* and *knowing that*. "Knowing how" refers to knowledge used to, say, ride a bicycle. This knowledge is tacit as one can know how to ride a bicycle without the understanding of the physics or physiology involved. "Knowing that", on the other hand, renders the knowledge explicit, typically in the form of theories. By rendering knowledge explicit, it becomes possible to implement this knowledge. This leads to the familiar practice/theory distinction: "This knowledge is enacted practically rather than represented theoretically". Practical, therefore, refers to using tacit knowledge. The "practical" format of knowledge means that the knowers are living their experience, not conceptualizing it and therefore may have a difficult time communicating it.

Shai and Reich (2004) use "practical" in a similar sense, distinguishing between formalization which allows for transferability and "practical experience that is rooted in context" which is not formalized. Thus, design knowledge that is heavily contextualized is "non-transferable" or, in other words, is difficult to communicate.

On the one hand, we have the "practical" as being non-implementable due to its tacit, non-communicable state; on the other hand, we have the idea of "practical implementation". When Carlson-Skalak, et al. (1998) speak of the "practical implementation of this approach" , one might interpret the "practical" as "real" rather than non-cognitive. Alternatively, one might claim that, although it may be difficult to move from the practical to the cognitive, it may be quite feasible to move from the cognitive to the practical, which appears to be the case here. Hence, Carlson-Skalak et al.'s "practical" can refer to the non-cognitive. If the practical is non-cognitive, it does not follow that the cognitive is non-practical.

The work of Arendt (1958) provides a nice contrast to the non-cognitive, mundane of "practical". As a social theorist, Arendt was concerned with preserving the new: "The new always happens against the overwhelming odds of statistical laws and their probability, which for all practical, everyday purposes amounts to certainty; the new therefore always appears in the guise of a miracle". We can contrast the word "new" with the word "practical". Occurring alongside "everyday", Arendt's use of the "practical" coincides well with the idea of the non-cognitive and mundane. The "new" on the other hand, is looking for the improbable, for a miracle – in stark contrast to science which prefers the probable and eschews miracles. This distinction raises some rather important questions. For instance, what is education all about? Do we teach students the "practical", what they "need" to know, to be "productive" members of society, to fit into societal structures? Or, do we teach to promote the new, to bring about change in the face of the "overwhelming odds" and in so doing deliberately create the possibility for citizens to *not* fit into the old societal structures? The same questions apply to engineering, both in terms of education and products. Should graduating students readily fit into the prevailing engineering enterprise, or should they bring the new? Should engineering products fit into the prevailing technological and social structures, or should they bring about the new? And is this "new" the same as innovation?

5.4 Practical as Deliberation

Schwab (1969) makes a plea for what he terms the "practical", opposing the notion that the "practical" refers to "easily achieved, familiar goals which can be reached by familiar means". Instead, in what could arguably be called his closing summary, he states (with the first sentence of the paragraph deliberately omitted):

> "It treats both ends and means and must treat them as mutually determining one another. It must try to identify, with respect to both, what facts may be relevant. It must try to ascertain the relevant facts in the concrete case. It must try to identify the desiderata in the case. It must generate alternative solutions. It must make every effort to trace the branching pathways of consequences which may flow from each alternative and affect desiderata. It must then weigh alternatives and their costs and consequences against one another and choose, not the right alternative, for there is no such thing, but the best one".

From an engineering perspective, Schwab's statements could easily be interpreted as a plea for good design. But Schwab is not referring to engineering design at all. He is, in fact, speaking to teachers, and to teachers of teachers, within a classroom setting. When dealing with issues in the classroom, Schwab is advocating careful attention to context rather then applying universal principles and methods. As for the "it", it is *deliberation* as contained in the missing first sentence: "Deliberation is complex and arduous."

For Schwab, the practical is so deemed because the context matters a great deal. Universal laws and principles can only take us to far. In the context, we must take note of the details and those details affect the deliberation. Since it is not about universals, the "who" matters: it makes a difference if one person is in the given context rather than another, as the result of the deliberation could be different.

But what is subject to deliberation? According to Aristotle (1962), we deliberate over those things where our action has an effect. Hence, we do not deliberate over the setting of the sun. We are more likely to deliberate on that where the discipline is less exact. We do not deliberate about the ends, but only the means to attain those ends. Within engineering, this means we do not question whether or not the need must be addressed, but rather how the need will be addressed.

Because we deliberate on those things where our actions have an effect, deliberation is also about *action*. The idea of action returns us to Arendt (1958) and the "new". The "new", while countering the mundane side of "practical", is very much about action, for to perform an action is to work against the probable, against the overwhelming odds, in an effort to create something new. Furthermore, action demands that there be a "who" who can carry out this action. The "who" once again reminds us of the importance of context as universals can, at best, reveal but a partial "who". The "who" also reminds us that, if engineers hope to exercise deliberation, individual people must be taken into consideration.

It is difficult to find a use of "practical" in the above excerpts which correspond to Schwab's concept. Heylighen and Bianchin (2012) do speak of deliberation in design. The "dialogic or deliberative conception of design" refers to a design environment where there is neither philosopher-king nor a random list to make the final decision. Deliberation is inclusive and speaks of cooperation between designers and users, with neither in possession of privileged knowledge. Ideas which are approved by the designers and deemed worthy must demonstrate their worthiness; deliberation is not just about judgments, but reasons for judgments. They go on to refer to a "'deliberative' idea of democracy where the value of inclusion is cognitive rather than practical". In this case, the use of "practical" is more in contrast to that of Schwab as this deliberation here is about rendering explicit, the "non-practical".

The idea that an engineer makes "trade-offs" and uses "cost-benefits" (Hertsgaard, 1983, p. 180) does provide some hint of Schwab-like deliberation in terms of weighing alternatives within a given context, but overtones of some economic model suggests downplaying the particular in favour of the more universal (economic) laws and principles. When Maier and Fadel (2009b) speak of "practical methods", this further suggests that engineers are not thinking like Schwab when they use the term "practical", for methods are very much about the universal. Methods, in contrast to deliberation, allow an engineer to enact an overarching theory with the added concern that little or no understanding of the theory is required (*e.g.*, what's the theory behind Failure Modes and Effects Analysis?).

Ullman (2010) believes that "[p]eople who prefer facts and details are literal, practical, and realistic" as opposed to those who "think in terms of possibilities, patterns, concepts, and theories [and who] are looking for relationships between pieces of information and the meaning of the information". According to Ullman, the designing engineer should lie somewhere between these two. Ullman's use of the term "practical" does not speak directly of deliberation but it does seem to align with Schwab's disdain for the practical as "familiar goals" and "familiar means". On the other hand, Ullman's "possibilities" (not "practical" in his case) and what follows sounds very much Schwab's "practical as deliberation". Thus, the ideas are similar, but the terminology is not.

5.5 Practical as Alignment

In the physical world, alignment typically refers to putting several objects on the same line (usually imaginary). The purpose of the alignment may be structural, such as aligning the loads with the support to reduce the stresses in the members; the imaginary line in this case is akin to force lines in a free body diagram. Alignment may also be desirable to assist in assembly, such as visually lining up several holes to facilitate the insertion of a bolt or pin; here, the imaginary line is a line of sight. In a similar vein, we can align visually for aesthetic purposes, such as aligning the tops of windows in a building. These tangible forms of alignment have analogues in the engineering design world.

Structural alignment speaks to the physical limitations placed on design, with the science-based "real" as the imaginary line. The design of a perpetual motion machine is not considered practical as we are told that such a machine is not theoretically possible and none has been successfully built. In manufacturing, it may not be considered practical to machine a part out of a hard or brittle material, or to machine a feature where the tool does not have proper access to the face of the workpiece.

Assembly-related alignment corresponds to design where the end can be seen from the beginning. The line of sight here represents a problem-solution trajectory, a path which is fairly clear, free-of-obstructions, connecting the problem to the solution. This is one form of "practical" which Schwab (1969) refers to as "easily achieved, familiar goals which can be reached by familiar means". The familiarity is the result of encounters we have had in the past, such as through education or some kind of experience. The imaginary line represents the relatively straightforward design process of an earlier problem with a successful solution. A sufficient number of elements of the new problem seem to align with the old problem, leading us to believe that, by following the old line with the new problem, a successful conclusion will be reached. Thus, when Braha and Reich (2003) speak of their "mathematical framework" as providing "ideas for improving practical processes and insight regarding their outcome", the processes are deemed "practical" as they clear the pathway to the "outcome", or solution.

A desire to clear the pathway from the problem to the solution speaks of a desire not to rock the boat, "to live in the modern world … [and] … minimize dissonance" as Schwab (1969, p. 8) puts it. Ullman (2010) refers to these as the "Preservers", those whom he also called "practical" as opposed to the "boat rockers". Some consider the "Preserver" as virtuous since staying under the radar allows things to proceed smoothly.

For Schwab (1969), praise for this kind of "practical" is ill-deserved, as this status is gained "in virtue of what they leave out". Although the *Practical as Real* may scoff at the contrived for leaving things out, *Practical as Alignment*, too, leaves thing out (apparently in a good way). It is quite possible, for example, that some features of the new problem do not align particularly well with the model problem and some force-fitting might be required to maintain the alignment. Furthermore, those features of the problem which cannot be aligned even with considerable force-fit are liable to be excluded from problem formulation. In other words, much of the solution is already decided; what is needed is to make the problem to fit the pre-determined solution. "Practical" in this way can take on the meaning of finding or re-formulating the problem to match the solution or, alternatively, putting the needs of the designer ahead of the needs of the user and other stakeholders.

The "practical", alignment-oriented engineer might object. All after, not *everything* can be included; some things must be left out; only that which is truly "needed" is included. If the "practical" engineer uses "science for the betterment of mankind" while "making trade-offs" and "cost-benefits", presumably science (and its ally mathematics) and economics (and similar models) are automatically included. But what about the "betterment of mankind"? How can an engineer discern what constitutes "better"? Who or what might "mankind" refer to? Does the term imply some kind of equity or is inequality acceptable or expected?

For some engineers, these questions are side-stepped as there seems to be this sense that "better" is somehow built into the system. If you keep pushing the "system" (itself ill-defined) in the direction (also ill-defined) it's already going, things will be fine. Many times, I have heard my engineering students say, "well, that's the way the world works", alluding to one neoliberal view of reality as "the way things are" (Flew, 2012, p.53). It does not appear that these students view themselves as those who alter the system. The "practical" engineer is the system-preserving engineer.

Some seek to explicitly bring people into the engineering arena, as they are all too often left out. Fila et al. (2014), for example, see engineering as "a profession that will solve human problems and thereby improve the lives of people" and present a figure which "calls attention to the humanistic roots of engineering, namely, that all engineering takes place in a human context". But what are the "humanistic roots" of engineering? The "roots" seem to imply the source of the problem for which engineers find the solution, *i.e.*, all problems originate among people. But "roots" normally refers to historical roots. Are the historical roots of engineering "humanistic"? Is this wishful thinking on the part of Fila et al.?

A quick review of engineering history shows that the historical roots are anything but humanistic. Modern engineering education clearly grew out of a military context (see, for example, Grayson, 1993) and engineering education is still based on a military model (O'Neal, 1994). "Civil" engineering tells us that, once upon a time, it was considered novel to use engineering for non-military purposes. Lucena et al. (2010) trace engineering's explicit support of imperialistic states as they set up colonies, and imposed their brand of order on the colonized. The engineers were actually known as military engineers. Is colonization a form of "betterment"?

If "war is politics by other means", the famous words attributed to Clausewitz, and if engineering roots are found in the military, then engineering is squarely in the political arena. The same holds true of today. Perry, the committee chair for Grand Challenges (NAE, 2008), who speaks of "formidable political obstacles" is himself involved in politics, for he is a former U.S. Secretary of Defense and an "expert in U.S. foreign policy, national security, and arms control" (NAE, 2016).

The "practical" engineer who insists that engineering is apolitical and ahistorical will invariably carry out the engineering in keeping with historical trends and dominant political values; these values may not be in keeping with the values of the engineer. When things go wrong, the "practical" engineer will be bewildered, much like "[a]n old ruling class … when faced with a new massive social movement" (Hertsgaard, 1983, p. 178) or the nuclear engineer when faced with opposition.

6 CONCLUSION

The "practical" takes on a wide range of meanings within engineering design discourse, promoting a wide range of values in the process. The *Practical as Ethical* stresses to engineers the importance of carefully accounting for the needs of the users and stakeholders affected by their product. For some, the "practical" compromises ethical concerns as it focuses too much attention on the general population at the expense of immediate clients. The *Practical as Real* tries to separate the messiness of the real from the containment of the contrived and urges engineers to downplay the value of the contrived, such as the educational experience. The *Practical as Non-Cognitive* distinguishes between the tacit *knowing how* and the explicit *knowing that*; tacit knowledge does have value, but explicit knowledge aids communication and implementation. The *Practical as Deliberation* tells engineers not to let universal principles determine their decisions; good decisions, with positive impact, demand an attention to the details of the context at hand. Finally, the *Practical as Alignment* encourages engineers to streamline the design process. In so doing, they risk leaving out too much.

Some of these values are mutually supportive, for both *ethics* and *deliberation* are calls to action. Some of these values work at cross-purposes: the *real* wants the messiness of the world with all the trimmings; *alignment* insists that something be left out to streamline the design process. The *non-cognitive* favors the mundane; *deliberation* focuses on the peculiarities of context.

A critical look at the term allows engineers to assess their own values and be more aware of how the very use of "practical", with its generally positive connotations, can influence their thinking and implicitly direct design goals. It is the "practical" urge to streamline that arguably presents the greatest risk to engineers: in downplaying the historical and political, engineers will necessarily find themselves working in keeping with historical trends and dominant political values: these values may be in direct contradiction to their own. Within design education, students' attention needs to be drawn to their casual use of "practical" as the term speaks not only of technical qualities, but of the values, often unspoken, embedded in the engineered product. Discussions centered around the "practical" can provide a common ground to explore both values and technical merit in an engineering context.

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