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ABSTRACT: In 1998, a lead researcher at a Midwestern university submitted as his own a document that had 64 instances of strings of 10 or more words that were identical to a consultant's masters thesis and replicated a data chart, all of whose 16 entries were identical to three and four significant figures. He was fired because his actions were wrong. Curiously, he was completely unable to see that his actions were wrong. This phenomenon is discussed in light of recent advances in neuroscience and used to argue for a change in the standard way engineering ethics is taught. I argue that engineering ethics is better taught in the form of a design course in order to maximize "somatic" learning.

See no evil

In 1998 a university in the Midwest fired a lead research engineer for plagiarism. The researcher (hereafter Dr. M) had solid credentials: according to the Scitation database, he had co-authored at least two dozen articles in the five years he had worked for the university's research institute and achieved an outstanding record of securing grant dollars. Dr. M was instrumental in obtaining a $5 million grant from the U.S. Air Force for studying the effects of fatigue on titanium, a key ingredient in turbine blades. As principal investigator, Dr. M constructed a machine to accelerate the process of fatigue-to-failure by superimposing a 20 kHz (near ultrasonic) vibration over a 2 kHz signal. If the device worked (later tests showed it did not), it would have proven extremely useful for this and similar fatigue studies.

As is typical, a sizeable cadre of grad students worked on the various facets of the project under the terms of this five-year grant. But for the stress-inducing device, Dr. M was assisted only by a consultant, hired (July 1997) from *outside* the institute, who six years earlier had done fatigue research on titanium and had captured the results in his own 1991 master's thesis. Less than a year later, Dr. M submitted a paper to an academic journal listing himself as sole author. An attentive co-worker, aware of the master's thesis, noticed uncanny similarities between it and Dr. M's journal article and drew this to the attention of the head of the institute's Structural Integrity Division. Careful investigation revealed three central acts of plagiarism: (1) "64 identical word strings of ten or more consecutive words….[some of which] constitute entire paragraphs of precisely identical text of technical writing, including punctuation"; (2) a table that "consists of test specimen failure data for 16 experiments, each of which is identical in result, to four significant digits, to the test data" in Table 5.1 of the master's thesis; (3) the manuscript submitted to the journal refers to footnotes [12] and [13] which match those in the master's thesis, but the manuscript itself has only ten footnotes![*]

After a lengthy in-house process—itself a model in procedural justice—Dr. M was fired by the university. Dr. M stridently maintained his own innocence. He hadn't copied anyone's data; rather, he successfully *replicated* the data of the masters thesis. He maintained this position in the face of the fact, well known in the field, that "cycles to failure" vary by as much as 50% from

[*] This case is a matter of public record. But since I am interested in the shape of Dr. M's crime rather than his identity, I only refer to the case by its number, 1999 CV 05683. Full text of the ruling made in the Montgomery County Common Pleas Court is available online at http://www.clerk.co.montgomery.oh.us/pro/image_onbase.cfm?docket=5667438. This ruling was upheld by the Second District Court of Appeals. The appeal, Case No. 19476, is also a matter of public record: http://www.sconet.state.oh.us/rod/docs/pdf/2/2003/2003-ohio-1852.pdf (Webcite accession number: 2003-Ohio-1852).

sample to sample. Indeed, there is normal variance from one sample to another within his set of 16 data. But Dr. M maintained that his set of 16, each of which varied widely from the others in his set, nevertheless matched all 16 data for cycles-to-failure for samples in the masters thesis (to four significant figures!). To defend himself, Dr. M produced a supplemental paper in which he claimed that he was *trying* to achieve identical data and did so by rapid mechanical increase of the gain at "precisely" the same time of breaking as each of the 16 specimens in the masters thesis. If the unscientific nature of his intent (what reputable scientist aims at replicating data to four significant figures?) is disregarded and grant the fantastical claim that by using his *wristwatch* he was able to interrupt a 20,000Hz signal at precisely the right moment, there is still the incriminating fact that Dr. M "could not produce any lab notes, test data records or test samples." (1999 CV 05683).

Somewhat surprisingly, after being fired, Dr. M filed suit against the university for a long litany of grievances, including libel and slander. It became evident in the process that Dr. M's strategy to recover his honor entailed aggressively undermining the integrity of his immediate supervisor (i.e., the head of the Structural Integrity Division who brought the formal charges that precipitated Dr. M's dismissal) by means of a deposition that was often as petty as it was lengthy (15 hours). Dr. M lost the case. And he lost the appeal. And he lost the appeal after that; the state supreme court flatly refused to hear the preposterous case. The university spent $198,000 exonerating itself.[1]

Practical Reasoning and Somatic Learning

The curious behavior of Dr. M is in some respects oddly similar to a class of psychiatric patients with severe neurological trauma to the ventromedial sector of the prefrontal cortex. I venture to make this comparison not in order to *explain* Dr. M's behavior. (After all, there are many plausible explanations for Dr. M's transgressions.) Rather, I draw the comparison in hopes of making the case that the teaching of ethics may yield correlative changes in behavior, but only if, key areas of the prefrontal cortex are repeatedly activated. Of course, this is not a *sufficient* condition for compelling behavioral change (students are not automatons). However, activity in the prefrontal cortex is *the sine qua non* of practical reasoning. Thus a little detour into neurobiology may shed light on the way ethics is learned. After this excursus, I shall argue that engineering design epitomizes the kind of prefrontal stimulation needed for somatic learning and thus ought to top our list of pedagogical strategies for teaching engineering ethics.

Much can be learned about practical reasoning by observing those who are physically incapable of doing it. The most famous example is Phineas Gage, the 25 year-old railroad worker who in 1848 survived an explosion that drove a three-foot, thirteen pound tamping rod through his cheek and out through the top of his skull. As startling as his survival was, his instantaneous personality overhaul was perhaps even more startling. Although his recovery—both mental and physical—appeared to be complete after two months of convalescence, Gage had permanently lost the capacity to make good choices. Instead, witnesses call him

> fitful, irreverent, indulging at times in the grossest profanity which was not previously his custom, manifesting but little deference for his fellows, impatient of restraint or advice when it conflicts with his desires, at times pertinaciously obstinate, yet capricious and vacillating, devising many plans of future operation, which are no sooner arranged than they are abandoned…"[2 (p. 8)]

Since Gage's case became public, there have been a handful of cases that have been far more carefully documented. In his masterful book, *Descartes' Error*, Antonio Damasio shows that practical reasoning is a function of the interplay between body and a constellation of several systems in the brain, especially those of the evolutionarily early limbic system (especially involving the amygdala and the anterior cingulate, both located in the ventromedial sector of the prefrontal cortex; pp. 70-71). These brain systems are pivotal for processing emotional awareness and generating agent responses. While the brain is sometimes able to compensate for damage in one section by learning to use other sectors, damage to the prefrontal cortex is unique in that damage cannot be compensated for by other regions, in particular by those involved in theoretical reasoning.

Damasio illustrates these claims with the case of a modern Phineas Gage he calls "Elliot." Elliot suffered from meningioma, a benign but fast-growing brain tumor. Expert surgery successfully removed the tumor as well as the nearby brain tissue that had been damaged by pressure. In terms of percentages, a relatively small part of the ventromedial sector of the prefrontal cortex (mainly right side, same elevation as but in front of the corpus callosum). Elliot's physical recovery from surgery was normal: "Elliot's smarts and his ability to move about and use language were unscathed" (36). But when he returned to work, he was crippled by an inability to make the simplest desicions. For instance, given the task of reading and sorting documents for the firm's clients, Elliot both understood the task and the material he read. What he could not do was *decide* which sorting metric he should use: the date of the document, the size of the paper, relevance to the case, etc. Silly criteria which normal adults would not seriously consider became for Elliot viable options. Having absolutely no reflexive heuristics for curtailing excessive analysis, Elliot could never begin much less complete the task. Not surprisingly, Elliot soon lost his job. He was subsequently bamboozled out of large sums of money and cycled through failed marriages.

An important datum for my argument is the fact that Elliot passed cognitive psychological testing with flying colors. His I.Q. was in the superior range; he was normal or above on the Wechsler Adult Intelligence Scale. His short term memory—for numbers, geometry, verbal strings, and visual images—was superior. As shown by the Multilingual Aphasic Exam, his language skills were normal (41). He scored in the normal range on Benton's standardized test, the Rey-Osterrieth complex figure test, the Wisconsin Card Sorting test, the Minnesota Multi-Phasic Inventory, and so on, endlessly. "After all these tests, Elliot emerged as a man with a normal intellect who was unable to decide properly, especially when the decision involved personal or social matters" (43). As ethics necessarily involves personal and social matters, Elliot's physical handicap was a moral handicap as well.

What finally emerged as the locus of Elliot's disability had to do not with his *cognitive* abilities, but with his emotions. Not that he was overemotional. Rather, "he was always controlled, always describing scenes as a dispassionate, uninvolved spectator." Even when recounting his own story, never "was there a sense of his own suffering, even though he was the protagonist" (44). Elliot himself retained factual memory of life before the tumor. He detected that formerly incendiary topics no longer generated *any* reaction, either positive or negative (45).

When Elliot was presented with a series of abstract ethical dilemmas, he performed perfectly normally (46-48). He was able to conceive complex problems, enumerate principles, rationally rank conflicting principles, generate a list of alternative courses of action, and predict how the scenario might evolve. But there is a twist: these tests of Elliot's ethical reasoning shared one common shortcoming: in each case, *no real decision was required*. Elliot successfully reasoned out the problems in a controlled environment but never had to chose. Elliot's own words make his plight more poignant:

> At the end of one session, after he had produced an abundant quantity of options for action, all of which were valid and implementable, Elliot smiled, apparently satisfied with his rich imagination, but added: "And after all this, I still wouldn’t know what to do!" (49)

Elliot's cold-blooded indecision, his ability to know but not to feel (45) resulted in an inability to live well. Ironically, Elliot's *body* did not forget what his brain could no longer learn. When presented with stimuli to trigger bodily states of fear, anger, and aggression, Elliot's galvanic skin response and heart rate rose appropriately. What Elliot was unable to do is to be aware of these somatic reactions. (Damasio delineates between the somatic responses or "emotions," and the brain's awareness of them, i.e., "feelings" (145).)

Normal adult living depends upon a finely tuned interplay between two master systems in the brain. The limbic system is that "system of systems" in the brain that is embedded in feedback loops with the rest of the body. It both reads cues sent to it by the body as well as readies the body to take action The other master system is the neocortex by which the brain is capable of conscious, rational thought. That the two systems are interwoven and interdependent is shown by the fact that activity in the neocortex (e.g., reading a scary novel) can stimulate the limbic system to prepare the body for action. In other words, normal adults *feel* fear in response either to bodily cues (e.g., the sound of an explosion or the smell of smoke) or mental cues (scary story). And in becoming aware of fear generated by mental cues, the limbic system completes the feedback loop with the body, readying it for action, as if the initial cues had come from the body. The rudimentary loop of communication between body and limbic system is "hardwired," as it were, and constitutes what Damasio calls the "*primary* emotions": "After an appropriate stimulus activates the amygdala…, a number of responses ensue: internal responses;…muscular responses; visceral responses (autonomic signals); and responses to neurotransmitter nuclei and hypothalamus." Human beings share the phenomena of primary emotions with many animals as nature's way to quickly accomplish useful ends: "speedy concealment from a predator, for instance, or display of anger toward a competitor" (132).

When Damasio teases out the process with more nuance, it becomes clear that perception and response is not a simple linear process, or even a single feedback loop, but an iterative, multi-layered one. The normal adult human not only has primary emotions, but also becomes aware of these emotions. In Damasio's terms, becoming conscious of emotions offers the adult human "flexibility of response based on the particular history of [its] interactions with the environment" (133). The full range of human feelings cannot be accounted for by primary emotions. Rather, a higher order set of mechanisms, "secondary emotions," occur

> once we begin experiencing feelings and forming *systematic connections between the categories of objects and situations, on the one hand and primary emotions, on the other*. Structures in the limbic system are not sufficient to support the process of secondary emotions. The network must be broadened, and it requires the agency of prefrontal and of somatosensory cortices. (134)

While the conscious brain is coping with its awareness of emotion, networks in the limbic system

> Automatically and involuntarily respond to signals arising from the processing of the [emotional] images. This prefrontal response comes from dispositional representations that embody knowledge pertaining to how certain types of situations usually have been paired with certain emotional responses, in your individual experience. In other words, it comes from *acquired* rather than *innate* dispositional representations…. (136)

Not only is wisdom habitual, the habits that constitute wisdom are emotional in nature. Secondary emotions (as well as our awareness of them) are *crucial* to the proper exercise of practical reason. The location of these emotions cannot be mapped onto any one region of the brain. Rather, awareness of emotion (feeling) is a property that supervenes on the entire iterative network of brain systems enmeshed with the body. Unless we have such shortcuts ready to hand, we would be lost in a hopeless morass of endless calculations of possibilities and re-calculations. Such was Elliot's plight. When faced with a test that asked him to draw cards from one of three stacks, each of which had an unknown pay-off and penalty rate, he could only resort to *primary* emotions and was unable to form emotional reflexes toward the high-risk deck. This prevented Elliot from learning from experience; every draw was as if his first. In contrast, normal adults maximized *long-term* earnings because they instinctively began to shy away from the stack that had the highest regular pay-off but also the devastating occasional penalty. Such learning required secondary emotions, which is to say, awareness of impending future pains: normal adults grew increasingly nervous that the next card turned from the high stakes pile would be a penalty card depriving them of all their winnings and quickly learn never to draw from this pile (212-222).

Damasio calls these emotional habits "somatic markers."

> *[S]omatic markers are a special instance of feelings generated from secondary emotions.* Those emotions and feelings *have been connected, by learning, to predict future outcomes of certain scenarios*. When a negative somatic marker is juxtaposed to a particular future outcome the combination functions as an alarm bell. When a positive somatic marker is juxtaposed instead, it become a beacon of incentive. (174)

Somatic markers function as embodied heuristics for pragmatically shortening in one's list of live options.

Because of the role that the limbic system plays in secondary emotion feedback loop between body and brain, those patients with damaged prefrontal cortex are unable to access somatic markers that have been learned. Thus Elliot's body responded was able to generate *primary* emotions. But because he could not be *aware* of these primary emotions. In other words, whether primary emotions were generated by the sensatory loop or by the imaginative loop, Elliot was unable to construct secondary emotions that normally arise in response to this awareness. *Elliot was neither able to feel the guidance of older disposition nor educate new ones.* In short, Elliot could calculate but *never decide*: "And after all this, I still wouldn't know what to do!" (49)

To summarize Damasio's claims:

1. The brain does not relate to the body as driver to car. In fact, the term "brain" bewitches us to imagine a unified control center. In contrast, the brain's 10 billion neurons (each of which communicates to other *nearby* neurons) are organized into overlapping systems. There is no one-to-one correspondence between a given cluster of neurons and a give human function.
2. One system of systems (the amygdala and the anterior cingulate are "prime players" of the limbic system; 133) is entangled with the rest of the body by a combination of neurological and biochemical pathways. Another system of systems (the neocortical) is entangled with the limbic system, and thus with the body as well.
3. Secondary emotions arising from the limbic system's response to the neocortical awareness of primary emotions are dependent on learned, embodied pathways (in Damasio's language, "somatic markers"; 165-222).
4. Wisdom in practical reasoning is crucially dependent upon secondary emotion, which is to say on *felt* tendencies to respond one way rather than another. Importantly, these tendencies or dispositions are felt *somatically*.

Missing somatic markers

I juxtapose Elliot to Dr. M in order to make the following suggestion: if felt dispositions (somatic markers) play a crucial role in practical reasoning, then faulty practical reasoning can be expected *both* from those who are physically incapable of processing secondary emotions (Elliot) as well as by those whose somatic markers are *underdeveloped*. Here "underdeveloped somatic markers" does not indicate a physical deficiency, but an educational one. We expect a novice to have less-developed reflexes than an expert practitioner. So we are surprised to find lack in those who have logged enough years to know better. Because Dr. M's crimes and his subsequent aggression left his peers dumbfounded, the following is at least a reasonable line of inquiry: did Dr. M suffer from underdeveloped somatic markers? If brain injury can be ruled out, then underdeveloped somatic markers may imply a correlative lack of *bodily* engagement with the morally formative practice. In Dr. M's case the evidence may be speculative at best. But there is evidence of poor laboratory skills. According to Dr. M's own testimony

- He retained neither raw notes from the experiments nor broken samples of the 16 tests.
- No fellow researcher could corroborate his reported experiments.
- He claimed that exact replication of another's data was his intention. (This explanation was offered *after* it came to light that each datum in a given set varied from its neighbors, therefore, how could he possibly replicate data that exactly matched the 16 results of another researcher?)
- He attempted to achieve this by mechanical interruption of the process, in effect, forcing each sample to break. (Obviously, this is contrary to the intention of the experiment.)
- He defended his ability to interrupt a 20,000 Hz vibration with enough accuracy for a cycles-to-failure reading accurate to four significant figures (apparently armed only with his wristwatch).
- The original report consisted of 16, and only 16, matching data. He later claimed to have used an "average testing method" on *more* than 16 data to achieve the astonishing results.
- He claimed to have made a conscious decision not to cite the master's thesis on the grounds that it was his scientific prerogative when and whether to cite another's work. Apparently, Dr. M does not consider teamwork as inherent to good engineering practice.

I suggest that it is at least plausible that poor lab skills may be correlative with underdeveloped somatic markers. This is not to say that Dr. M was emotionally flat in the same capacity as Elliot. But in ways similar to Elliot, Dr. M evidenced poor practical reasoning followed by a striking lack of secondary emotions: no horror at the crime, no shame for having defrauded his colleagues, etc. Horror, shame and the like involve secondary emotions requiring him to *feel* abstract ideals.

My real point is not to castigate Dr. M once more, nor to *explain* his extreme behavior. Rather, my point in juxtaposing Elliot and Dr. M is to underscore the vital need for intentionally providing pedagogical opportunities for students to develop somatic markers. To cite Damasio once more:

> The automated signal protects you against future losses, without further ado, and then allows *you to choose from among fewer alternatives*. There is still room for using a cost/benefit analysis and proper deductive competence, but only *after* the automated step drastically reduces the number of options. (173)

In sum, *engineering ethics courses need both a theoretical component and a somatic component*.

Teaching Ethics by Means of Design

It is common knowledge that today's engineering curriculum leans heavily toward the theoretical. What is needed are curricula that engage students at the somatic as well as the theoretical level. I don't mean simply hands-on learning—though that is crucial for good engineering program. I mean also to suggest a kind of hands-on learning that enables students to experience secondary emotions. Positive feelings such as pride, ownership, loyalty to one's teammates, as well as negative ones such as abhorrence and disgust at substandard performance, are indications that somatic markers are being formed.

Design thinking engages students in all three domains of learning.[3] In addition to cognitive reasoning (analysis and problem-solving), design thinking also engages students at the level of effective and affective learning. In light of Damasio, effective learning is broader than, say, hands-on prototyping. Effective learning extends to bodily skills, memories, and tacit knowledge[4, 5, 6] that go into the formation of somatic markers. Similarly, affective learning explicitly involves the emotional component of somatic learning. Design activities (broadly construed) engage students on all three levels because design is an inherently social enterprise involving crucial skills of negotiation, deliberation and compromise.[7, 8, 9] And precisely because design is social, design exercises can function as exercises in ethics.

Just as the intentions of designers are embodied in artifacts, so too ethics cannot be understood apart from the *process* that produces the artifact. Indeed, moral value can be embodied in the artifact. (A nefarious example is the 200 underpasses that Robert Moses had constructed in New York City whose extra low clearance (a mere 9') effectively denied minority-filled busses access to public beaches.[10]) Conversely, to the extent that design degradation results in poor artifacts, many so-called ethical dilemmas may not be due to evil intent per se, but involve rather "the sociology of a mistake."[8] In other words, some design degradation happens because social process tends to compound and magnify seemingly tiny mistakes. Such magnification transcends the efforts of individuals, while the processes themselves are unavoidable as they are inherent in the production of artifacts. These facts shows engineering ethics to be broader than solving dilemmas or assigning blame. Engineering ethics is about fluency in the design process.

Whitbeck describes four ways in which ethics and design problems are similar:

- There is virtually never a singularly correct solution or response.
- Some solutions are untenable—there are wrong answers even if there is no unique right answer—and some are better than others.
- Each solution may be better than the others in certain respects while being inferior in other respects.

- None of the solutions are clearly superior to the others.[11]

The similarity of ethics to design suggests that ethics enters the design process not as a "sub-problem" to be solved in isolation. Just as design is iterative in nature, with no clear starting and ending points,[12] so too ethics is not a mere ingredient to be added independently of other concerns such as material properties or cost. Rather, ethics permeates the entire process, just as design thinking does. This implies that fluency in ethical discourse is assimilated simultaneously with design discourse.[7]

As design is proactive, so too is ethics proactive. Design is not what engineers do only when things go wrong. Ethics is both evaluative (it *is* of concern when things are "not good") and proactive (ethics is of concern *not only* when things go wrong). Ethics is an intentional enterprise that projects a positive vision of the Good, of what human life is for, and embodies this vision in artifacts, processes, and infrastructures.

Design is the thoughtful response to problems that are "wicked." Ethics problems and design problems are wicked problems because they share the following features: they have no definitive formulation, no clear rule delineating when to stop solving, and no immediate, ultimate testing criteria. Wicked problems neither afford the luxury of trial-and-error methodology nor offer stakes low enough to allow the planner to fail. Each problem is unique and yet each one can be viewed as a symptom of a string of problem(s).[13] The ambiguity of design problems means that the most useful instruction to offer design students is practical tips or heuristics.[14] B.V. Koen has shown that heuristics are not only essential to best-practice engineering; heuristics are the means by which *all* practical reasoning takes place. In other words, human rationality copes with chaotic and dynamic contexts by employing time-tested "rules of thumb." Just as engineering heuristics require skilled judgment at every turn (e.g., when is the appropriate time to freeze a design?), so too ethical heuristics are useful shortcuts for knowing how to proceed when faced with moral ambiguity.

Course Description: Somatic Learning and the Design Exercises

The latest Carnegie Report, "Educating Engineers: Designing for the Future of the Field," recommends that educators combat "widespread emphasis on theory over practice" by involving students in real-world problems and ethical dilemma.[15] Consistent with this recommendation, our objective was to utilize design methodologies to solve the single greatest problem faced by engineering ethics educators: the need to help students shift from analytic to synthetic mode of reasoning. Synthetic reasoning is defined here as not only the ability to meld insights from non-engineering fields (some researchers have called this "cross-content" or "cross-domain transfer.[16] (pp. 131-132) I also take "synthetic" to mean reasoning that involves the whole person, a blend of cognitive and emotional processes.

Since Whitbeck's 1995 article, a growing number of ethicists have employed design as a rubric for teaching ethics.[17, 18] What follows is an attempt to enrich the pool of pedagogical strategies and keep alive the conversation about best teaching practices. The course in question was team taught in the spring semester of 2008 at the University of Dayton. I do not attempt to be exhaustive in my description. I focus on those features that show most promise for triggering somatic learning.

Emotional participation was heightened by use of games[9]: design teams masquerade as engineering firms competing for "financial" contracts by designing winning responses to "Requests for Proposals" (RFP) given by instructors. The design process associated with each RFP was restricted to the "Concept Design" phase.[19] Thus the process is able to be repeated ten times in the semester. While competing for financial contracts, firms are assessed daily operational costs. The object of the game is to keep the firm afloat. Granted, there are dangers to using games. For example, when in competitive mode, students tend to suppress ethical reasoning.[20] But we tried to separate the course-wide competition from the design process itself. In other words, during the design process students were more mindful of team playership within their firm than their standing against other firms. The RFPs emphasize qualitative rather than quantitative design in order to reduce the reflexes to expend too much time on detail design or on overly technological solutions.

Open-endedness has been shown to be a component of both design and ethical reasoning.[21] Each RFP was thus intentionally open-ended, requiring student teams to investigate a wide range of the design possibilities. For example, an early RFP calls for design of an Eco-Toy aimed for an age group of the team's choosing that would, in the playing, inculcate not merely facts but also values, behaviors, and emotions regarding some team-determined aspect of environmental sustainability. So, the design team has to decide not only (1) the focus and scope of the environmental "lesson," but also (2)which lesson from a vast array of possibilities is significant and packageable as an age-appropriate toy, as well as (3) whether choice of construction materials (recyclable or not?) may augment (or alternatively, stultify) learning.

Fourth, the design projects are given real-world feel by the combination of risk of failure, real-world problems, and evaluation by real people (hereafter "client-judges"). The sheer number of RFPs posed means that teams will fail, and fail often! Five teams in a class implies that each team can only expect to win 20% of the contracts. But only by failing often are teams afforded the opportunity to learn stubborn lessons from those multiple failures. (By contrast, standard design courses tend to have enough safety ropes that risk of failure is relatively low; disastrous designs can be proposed by students who, in the end, successfully pass the class. Success is virtually guaranteed so long as students keep plugging away.) The statistical chance of frequent failure is augmented by the fact that teams compete against each other in a winner-takes-all quest for dollars. This risk is somewhat offset by the incentive that the dollar value of each successive project increases so that by winning, a team can make up for some if not all of its previous losses. (This risk factor, obviously patterned after real world economics in which some firms swim and others sink, itself affords rich opportunities to teach ethics. Does one win at all costs? Should one member be singled out as the scapegoat when the team fails? How does a losing team pull together after successive failures in order to treat one another in such a way that creativity is more likely to happen during the next project? And so on.)

In addition to a real risk of failure, another sobering real-world component is brought to the task by the use of *realistic projects* and *live client-judges*. As an example of the former, the EPA has listed four areas in Dayton as Superfund sites. One RFP asks what to do with a house in Dayton bequeathed to the firm by a recently deceased uncle. Unbeknownst to the students, the neighborhood is sitting atop a toxic waste plume and select homes are being treated by the EPA for vapor intrusion by trichloroethylene. The RFP calls for the design team to make morally appropriate response. (Should the home remain vacant? Should neighbors be alerted for their own safety? Or should the danger be hushed up so that property values don't plummet? And so on.)

Finally, the synthetic nature of design thinking is augmented by the somewhat terrifying prospect of outside "client-judges." The RFPs are designed by the instructors. But as the course progresses, the instructors play a decreasing role in the design process. (We do continue in one important aspect: the daily "common time" includes both a recap of the financial standings of each "firm" and serious inter-team discussion of the interdisciplinary readings relevant to the increasing ethical density of each RFP.) In place of the principle investigators, "clients" are brought in from outside the classroom, to be interviewed by the students. These same clients then return to judge the designs—thus deciding the financial victor for each RFP—and to give immediate public feedback to the teams as to merits of each design. (Anything that can be called "good" reflects a moral aspect—albeit trivial in some cases. Thus "good" design can be used to teach ethics.) Clients will be drawn from both inside and outside the university including public school personnel, clergy, engineers, artists, and so on.

Every RFP not only has a built-in ethical component, the ethical components increase in ethical density as the semester unfolds. For example, the very first RFP aims at teaching teams how to trust each other by training each team member in an exclusive skill, and that only by working together can the design team succeed. Subsequent RFPs work on the assumption that artifacts *embody* morality and that designers *commit* ethics.[10, 22] In some cases the ethical component is quite blatant. Thus, a midway RFP asks for the design of a monument to Arthur E. Morgan, the "local genius" (local to Dayton, OH; the term is Schwehn's[23]) whose unique levee design simultaneously protected the floodplain and prevented reoccurrence of the 1913 flood that devastated Dayton, Ohio, killing 360 people. This RFP obviously requires students to research and assess Morgan's work in light of the historic, economic, recreational, and possibly the de facto race-dividing function of the Great Miami River in order to embody these aspects in their own monument.

The last RFP makes use of the tacit provision by ABET that instruction in ethics, while mandatory for undergraduate programs in engineering, could be taught in a way that fits the historical identity and character of the institution. In fact, "fittedness" (and the ability to read it) is itself also an ethical notion. Excellent engineering design is design that fits the context; one size rarely fits all. In this light, the last RFP called for designs of a prayer chapel in a specified empty room in the engineering building. University chapels range from the ornate (Notre Dame) to the austere (MIT). As the University of Dayton is a Catholic institution, founded by a religious order (Society of Mary) pledged to poverty (among other things), it would not "fit" to propose that the walls of the chapel be papered with dollar bills! But what then does fit? Marianist brothers, some of whom are employed by the university to teach biology, English, etc., were included in the panel of client-judges. Student design teams interviewed, researched, deliberated, negotiated, and compromised in order to achieve "satisfactoriness"[24] for the double-metric of fitting UD's historical character and fitting the curious stipulated location, namely fourth floor of Kettering Labs?! The process of dealing with questions of fit mean that the teams are forced out of the mode of "tunnel vision"—an all too common problem with today's young engineers[25]—and optimizing the design for multiple metrics.

There are a number of challenges to be worked out with the use of design in the teaching of ethics. One temptation, of course, is to load the design courses with so many numerical calculations that students are barely able to accomplish one design per semester. Undoubtedly, the quantitative approach to design makes for skillful engineers. However, we opted for a greater number of design projects (ten in all), on grounds that the bulk of ethically laden conversation happens in the conceptual phase. The culmination of the design process in our class was the building of "shmock-ups." We defined "shmock-up" as a “first attempt” prototype intended to display both form and function as simply as possible. A shmock-up is assembled from common everyday objects that do not need to be purchased: cardboard, paper clips, cups, utensils, rags, pencils, popsicle sticks, and so on. Despite their simplicity, the very act of constructing these crude prototypes contributes to an increase in student's somatic learning, because their shmock-up must express those formal and functional features given top priority by the team.

In addition to all the hooks for emotional engagement described above, student teams had to *defend* their designs before peers, instructors, and the panel of client-judges. The conquering of fear of public speaking by means of a well-crafted defense has obvious emotional attachments. Bucciarelli calls this conversation a "synthetic interchange" because designers must communicate what they have come to know tacitly to a group of judges who do not share their tacit knowledge.[7] This meant that students had to speak not only in the in-house lingo that develops among those who've read common readings and worked side by side for an entire semester. They also had to learn how to translate their design discourse into notions of good that client-judges could understand. The act of verbalizing of value judgments and supporting reasons strengthens formation of somatic markers by being yet another iteration of the design activity. Just as important, this iteration is pervaded by both primary emotions (fear!) and secondary emotions (pride in excellence; camaraderie, and so on).

Conclusion

At the end of the day, my interest has not been to castigate Dr. M. Rather, I juxtaposed his case to the equally curious case of "Elliot" in order to argue that more consideration be given to somatic learning in engineering ethics courses. In particular, I argued that design exercises offer enormous promise for engaging students in somatic learning.

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