Deconstructing Engineering Design

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1 Abstract

Postmodernism has swept through disciplines from literature to philosophy, from politics to sociology. But what does postmodernism have to do with engineering or more specifically, engineering education? Postmodernism may be the cure to several common ills, such as students becoming overly reliant on engineering models or computer simulations, lack of diversity (both in design teams and in the designs themselves), and lack of accountability due to a belief that technology is ethically neutral. However, postmodernism also presents some thorny philosophical challenges to the engineer. In a world of relativism where all is interpretation and there are no absolute truths, what is the status of engineering knowledge? Can engineering education be deconstructed until there is no longer any meaningful definition of reality? While science and technology are the centerpieces of modernity, many point to computer technology in particular as a harbinger of postmodernity. It is important for engineering students to understand how our technological products have thoroughly altered the society around us and continue to do so. This paper explores some pedagogical approaches that can be incorporated into existing courses, suggests some structural changes that may be warranted in the curriculum, and emphasizes the necessity of an engineering education founded on the liberal arts.

2 Introduction

If modernism was founded on concrete, scientific reality; postmodernism has been built on contingent, divergent interpretation. Postmodernism has swept through disciplines from literature to philosophy, from politics to sociology. Lyotard defines the modern as dependence on grand or meta-narrative, i.e., some overarching or foundational truth. He then defines postmodernism as "an incredulity towards metanarratives."[1] Shawver summarizes: "In other words, it is a skepticism towards all grand theories that think they have the last word. The moderns, Lyotard tells us, believed in metanarratives. They were always thinking that they had found the final and correct theory, but postmoderns are more incredulous."[2] But what does postmodernism have to do with engineering or more specifically, engineering education? Engineering thought of as simply direct application of science to produce technology has little to do with postmodernism. For example, Shearer sees the two as nearly polar opposites: "There is, however, a curious dichotomy that pertains to engineering and the civilization it has improved; indeed, an ironic split. For, while engineering has to be a discipline that is linear to the core, the civilization itself — Western civilization, for now — has become postmodern, and postmodernism is least of all linear."[3]

In contrast to Shearer, engineering conceived as a discipline founded on creativity and trade-offs, as divergent thinking to select amongst multiple alternatives, as an interpretation of human needs and desires embodied in design, has much to do with postmodernism. Engineering has been defined by some as the ultimate postmodern activity. Yet engineering education does not sufficiently recognize the interdependent nature of the currents in engineering and the winds of change in society at large. Engineering students should be familiar with the broad strokes of the significant dynamics in our culture today, in part because good engineering design takes into account the nature of the user in intimate detail, in part because good engineering design infuses itself into the culture so that technology, as a cultural activity, becomes an interactive dialog between multiple streams of thought and action.

While the prophets of postmodernism and the advocates of science have jousted often, engineering has seen only small academic skirmishes, attracting little direct dialog with postmodernism. Most of the work has focused on how engineering education, and engineering itself, can benefit from a postmodern approach. Less work has focused on the reverse – how engineering affects postmodernism, though there is some notable work here, such as Mitcham's exposition on why engineers need to know some philosophy, concluding with the claim that engineers "are the unacknowledged philosophers of the postmodern world."[4]

3 Postmodern Engineering: Benefits and Challenges

Postmodernism may be the cure to several common ills in engineering education, including uncritical belief in scientific results, lack of divergent thinking, and lack of awareness of the bias in technology. Postmodernism eschews broad truth claims in favor of divergent interpretations based on varying worldviews. This more skeptical approach could be an antidote to the over-reliance students place on engineering models, especially when implemented on a computer. Oddly enough, the scientific approach should ingrain a healthy skepticism in engineering students trained in its method of hypothesis and testing, but like many others, engineers are often blind to the fallibility of scientific results. A postmodern emphasis on interpretative frameworks is also a motivator for diverse team-based work, where many different viewpoints are valued. Divergent thinking is an important factor in fully exploring a design space and identifying less obvious consequences of various design alternatives. Technology in the modern view is neutral, an entirely predictable and unbiased outcome of a scientific process of design. The postmodern view acts as a corrective, noting that technology design is certainly not unbiased and the resulting products are not neutral. This stance elicits stronger accountability for designs, as the designer is no longer an automaton simply carrying out a predetermined script, but rather is an active, creative participant interpreting requirements in a meandering path towards a technological product which is just one of many possible solutions to a problem. The designer is not an unbiased participant, and the creative act of design allows the engineer's particular perspectives and viewpoints (and also those of the manufacturer and distributor) to seep into the product.[5]

Postmodernism also poses some significant challenges to engineering. It questions the standing and authority of engineering knowledge and deconstructs engineering design as it does every other interpreted text within our cultural.

3.1 Status of engineering knowledge in the face of relativism

Because engineering model predictions very often match actual behavior, we are tempted to make unwarranted generalizations. Because it worked before, we assume it will work again. Because it worked on this, we assume it will work on that. Because our material constants seem to apply universally, we assume our customers will behave universally the same too. Models try to make universals out of particulars, but particulars often are exceptions to the rule. "Particularism has been hailed as the hallmark of postmodernism"[6]. Postmodernism questions all claims to absolute truth, including claims that engineering knowledge reflects ultimate reality. The postmodern critic points out that engineering knowledge consists of imperfect human models. A postmodernist would even consider material properties to be a human construction, an interpreted framework that we construct over reality.

Engineering models have predictive aspects (they attempt to foresee the behavior of real materials in future situations) and explanatory aspects (they attempt to explain the behavior of real materials in past situations based on certain "fundamental" principles). In both respects they can disappoint. Sometimes poorly understood principles (rules of thumb) can still provide "pretty good" predictions, but little is offered in the way of explanation. Sometimes alternative explanations provide predictions of equal accuracy, leaving one to wonder which model is "truer". Students are quite familiar with how their teachers often simplify a problem in order to get to a solution method that is tractable. This must seem very strange to them -- that we start out in search of a method of predicting how the real world works, but then immediately find the real world too messy, so we settle for a method that we can solve, but one that doesn't really predict very well. Engineers in the field know that these model simplifications often rule out practical use of the method in the real world. When model predictions are wrong, the model is "enhanced" in an attempt to handle the mispredicted cases better. For example, earlier models of metal strength did not accurately predict the useful lifetime of a locomotive axle. The models were then adjusted to include the concept of fatigue. Models that become too complicated may be so unwieldy that they lose their explanatory power. They might still retain their predictive power if one can use a computer to produce the predictions from the model. The computer model might be based on simulation of complex principles but it might also be a jumble to adjustments and fine-tuning in an attempt to improve the model to approximate reality better.

Are simpler models that provide imprecise and/or inaccurate predictions of any use then? In fact, yes. They provide ballpark behavior, sometimes bounds to behavior, and sometimes predictions of most likely behavior. When the models can be computed easily by hand, they provide a good validation check against computer-generated predictions. In this case the goal is a quick, rough estimate that is so simple as to make mistakes unlikely. The ballpark answer can then be used to validate a computed answer that is highly precise, but may be completely inaccurate because of mistakes. Engineering models (regardless of complexity) are never perfect nor complete. But as long as they have practical utility, they serve their purpose. It is on this point that Vincenti differentiates engineering from science (which desires completeness of explanation regardless of utility).[7]

3.2 Can engineering design be deconstructed?

Jacques Derrida deconstructed literary texts, showing how the seemingly coherent text with a single meaning was really a contingent interpretation, with multiple meanings. Can engineering design be similarly deconstructed? Perhaps. While the designer may have in mind a single purpose, that purpose is communicated only obliquely to the user through the design itself. An admirable design fits form to function so that the design itself implies the use. But this communication is never perfect. The user interprets the design, sometimes using it in ways the designer intended, sometimes in ways the designer never foresaw. The same design is used for radically different purposes by different users. In fact, some designers intentionally allow the user to participate in the creative process by producing products that are extensible, adaptable, and customizable. Such designs treat the user not as consumer, but as collaborator.

Deconstructing engineering design breaks down false perceptions of universality. Assuming that technology is universal and generic blinds us to unintended consequences that result from concrete particular products that are exceptions to our so-called universal rules. Similarly, a universally generic technology can be treated as ethically neutral, but particular concrete technology is never neutral and always exhibits biases – tendencies to be used in certain ways. Thus deconstruction can be a healthy corrective that makes us all (designer, developer, manufacturer, user, disposer) responsible for technology.

Engineering testing can actually be a form of deconstruction. Testing generally proceeds along two tracks. One type of testing is qualification: verification that selected materials and purchased parts meet the standards set by the design. We also verify the workmanship, assuring that all assembly has been done according to plan. The other type of testing is model validation and it is this aspect that could be considered deconstruction. Testing of the particulars of a design is essential in order to determine if any of the "universals" assumed during the design were not truly universal. When a test of this type fails, we can feed this new information back into our models to help us improve them. Implementing tests that can disprove the model allows reality to deconstruct the model. Good interface design actually includes this type of feedback as an integral part of the normal operation of the machine: "Feedback is essential for safe and efficient operation… Perhaps because designers never expect things to go wrong, too little attention is paid to this most essential aspect of the use of artifacts."[8]

4 Engineering Postmodernism

Science is a discipline that attempts to explain how things work. Scientists hypothesize an explanation for an observed behavior and then experiment to prove or disprove their hypothesis. A hypothesis that holds up over many experiments may be elevated to the status of theory, and a theory that holds up against all testing may be promoted to the status of law. An admirable hypothesis/theory/law is one that is elegantly simple and has great explanatory power. It is thus a fundamental principle, an idea that can be incorporated into engineering models. Hypotheses that by experiment prove to have flaws can be reworked and adjusted to account for the new data. Thus the scientific approach is truly modern – our models of reality are ever improving, getting ever closer to absolute truth. Furthermore, the modern expects that our models will not only improve in accuracy but also broaden in scope. The ultimate goal for the modern scientist is the grand unified theory of everything – a fundamental rule for how things work at all times and places.

Some aspects of engineering also reflect the modern. Borgmann identifies them thus: "The distinctive discourse of modernity is one of prediction and control."[9] However, many other aspects of engineering suggest the postmodern. Information technology has been seen as the enabler and harbinger of postmodernism. Jean-François Lyotard, a leading postmodern authority, has noted the society transforming power of information technologies[1] which have changed the nature, meaning, and power of knowledge in our culture. Information technology has contributed to globalism by providing communication in the form of fast information transfer between many parts of the world (though some would note that the connections have not been justly distributed). It has contributed to individualism by giving public (in fact global) voice to anyone online. It has contributed to consumerism by providing a new way to shop. Of course shopping from home predates the Internet, from 800 numbers advertised on television to home shopping catalogs mailed out to millions. What is new about online shopping is the ability to quickly search for and compare products coupled with the ability to purchase with just a couple clicks of the mouse. Information technology has contributed to cultural relativism and multiculturalism as it has opened up the world of ideas and culture to anyone online. As Shearer puts it, "postmodernism…has arisen…partly because this technology is now nearly a global phenomenon, resulting in a more multi-cultured character to the media by which we know the world."[3] All these cultural forces (globalism, individualism, consumerism, cultural relativism, multiculturalism) support a move to postmodernism in one way or the other.

Not only the products of engineering, but engineering itself can be considered postmodern. Mitcham makes this point: "As we increasingly construct the world we increasingly recognize the world as constructed. As human beings have moved from a natural to … engineered world, surely it is no accident that … process has replaced substance, that knowledge is increasingly framed by economics and politics as much as cognitive methodology…"[4] Good engineering values divergent thinking, alternative solutions, and cultural appropriateness. Postmodernism has appropriated these same values. Divergent thinking recognizes the importance of varying perspectives. Engineering review of alternative solutions recognizes that there is not one right answer. Cultural appropriateness recognizes that all engineering (like all politics) is local. Perhaps we were postmodern before it was "post"? "The engineering design process embodies and exhibits precisely the kind of contingent, decentered, boundary crossing, and emergent ordering processes that postmodernity analyzes, explores, and celebrates. Engineers live but do not speak postmodernism."[4]

5 Postmodernism and Engineering Education

Engineering education focuses on technical issues, and rightly so. But a sole focus on the technical is not healthy. It is important for engineers to recognize the social and cultural forces they unleash with their products as well as the influence of society and culture on engineering design. In particular, postmodernism is an important feature of today's world that interacts with engineering in important ways that our students must recognize.

5.1 Pedagogical Approaches

Engineering education pedagogy can be attuned to postmodernism by emphasizing certain existing aspects of design education and identifying how postmodernism is tied to these concepts. Three examples are divergent thinking, alternative solutions, and cultural appropriateness.

Divergent thinking is an important skill in engineering design – the ability to see a problem and possible solutions from different angles. We each come to a problem with our own biases and opinions –our own worldview – that colors and filters how we see reality. This is a central tenet of postmodernism, that there is no one way to see reality. For engineers, divergent thinking is one way to identify unintended consequences of a design, resulting in design modifications to improve the safety, reliability, or usability of a design. As Lewis has noted, "No model is a catalogue of ultimate realities, and none is a mere fantasy. Each is a serious attempt to get in all the phenomena known at a given period, and each succeeds in getting in a great many. But also, no less surely, each reflects the prevalent psychology of an age almost as much as it reflects the state of that age's knowledge."[10]

Alternative solutions come about when brainstorming about potential methods of solving a specified problem. This task is a concrete application in divergent thinking. Finding real alternatives (not simply strawmen) allows the engineer to contrast and compare various possible approaches to a problem in order to select the best tradeoff between various design selection criteria and constraints. The existence of valid alternative solutions emphasizes the postmodern idea that there are different, yet equally valid perspectives on the same situation.

Cultural appropriateness is one of several design norms[11] that can be used to responsibly choose between various design alternatives using more than narrowly technical criteria. These norms help engineers to explicitly recognize the contingent nature of their designs. The norm of cultural appropriateness acknowledges that the same design can be interpreted very differently depending on the cultural context. Users from different cultural backgrounds see the design in a different light and thus may use it in a different way. In fact, the engineer may modify the weightings and priorities of design selection criteria, depending on the cultural milieu within which the technology will embed itself. Certain cultures may even yield a distinct set of alternative solutions that may or may not be viable in other contexts.

5.2 Curricular Approaches

The curriculum can be adjusted to provide engineering students with a better introduction to postmodern thought. A greater emphasis on design projects with appropriate guidance to include non-technical aspects can impel students to confront the ideas of postmodernism. However, students tend to quickly narrow in on the technical aspects, so it is usually necessary to make some part of the grade contingent on a consideration of broader, non-technical aspects of the design, exploring how the design will impact society and how society informs the design.

Sacks calls for the kind of breadth in engineering education that the liberal arts can provide as a means to appreciation of diversity, an important aspect of postmodernity: "Graduates should have the flexibility to adjust to the ever-changing professional environment and appreciate diverse approaches to understanding and solving society's problems. They should have the creativity, resourcefulness, receptivity and breadth of interests to think critically about a wide range of cross-disciplinary issues...."[12]

A purely technical engineering education makes it very difficult for students to see how postmodernism and engineering interact, since they do not have the framework to provide a perspective on this interaction. A strong liberal arts component is essential to provide the cultural leverage necessary to see technology as a cultural activity, one which becomes an interpretive interplay between the designer and the user. Van Poolen has noted this interplay and observes that technology is itself a hermeneutical (interpreted) text.[13] Although he concentrates on the performance of the text as it is transmitted from designer to manufacturer, he notes that the concept could be applied as well to the transmission of the technology text from manufacturer to end-user. Technology joins art, music, literature, politics, and the whole spectrum of human cultural activities as a medium of interpretation. Music is written by a composer and passed to a musician who interprets the piece while playing. The played piece is then interpreted once more by the listening audience. Technology designs likewise are written by a designer and passed to a manufacturer who interprets the design while constructing the product. The constructed product is then interpreted once more by the end-user. The end-user may even produce additional technology using the product, or use the product in a way unforeseen by the designer. In a sense the end-user is more like a second musician who picks up on the melody of the first and improvises upon the theme. Some of the improvised actions are dictated by the product, some are merely suggested. The end-users read the technological text and produce the "music" as they go.

So the liberal arts can be important qualifiers of an engineering education in two ways. First, they provide the context so students can make connections between technology and the rest of the culture. Second, they provide a metaphor that helps us understand technology by showing how artist and audience interact.

6 Conclusion

While engineers should understand postmodernism so that it gives them pause before using an engineering model, the lack of a center in this philosophy need not lead to despair. Engineering has shown by example that its models of reality, imperfect as they may be, are good enough. Along with Shearer, I "would worry about, say, crossing a bridge that a civil engineer had designed with irony in mind."[3] In the end actions speak louder than words. We need engineering to continue to maintain its claims about reality, recognizing that those truth claims may not be absolute or ultimate, but are practically true – in the sense that they are close enough and thus work in a pragmatic sense.

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[2] Shawver, L. Notes on Reading the Birth of the Clinic. 16 May 1998. http://www.california.com/~rathbone/foucbc.htm

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[5] VanderLeest, Steven H., "The Built-in Bias of Technology," *Proceedings of the 2004 American Society for Engineering Education (ASEE) Conference*, Salt Lake City, Utah, June, 2004.

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[8] Norman, Donald A., "Design Principles for Cognitive Artifacts," *Research in Engineering Design*, v4, n1, 1992, New York: Springer International, p. 46.

[9] Borgmann, p. 2.

[10] Lewis, C.S., *The Discarded Image*, p. 222-223.

[11] Ermer, Gayle E. and VanderLeest, Steven H., "Using Design Norms to Teach Engineering Ethics," *Proceedings of the 2002 American Society for Engineering Education (ASEE) Conference*, Montreal, Quebec, Canada, June, 2002.

[12] Sacks, Arthur B., "Human-Environment Interactions: The Initiation of a New Curriculum", *Proceedings of the American Society of Engineering Education Conference*, Seattle, WA, 1998.

[13] Van Poolen, Lambert, "Towards a Christian Theory of Technological Things," *Christian Scholar's Review*, v33, n3, Spring 2004, p. 368.

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