DESCRIPTION, PRESCRIPTION AND "BAD" DESIGN

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ABSTRACT
Design methodologies can serve the purposes of description, prescription, or the creation of norms. A given methodology can display features of all three. In such cases, does the presence of all three compromise the validity of the methodology? The mixing of the descriptive with the prescriptive is common in both science and engineering. Science often requires a theory (prescription) to enable us to make sense of what we are seeing (description). Within engineering, mathematics draws the descriptive and the prescriptive together; at first glance, mathematics appears merely descriptive, but the unwavering trust placed in its constructs give it prescriptive powers. Thus, one would expect models of the engineering design process to be ambiguous without diminishing the methodology. The normative presents its unique challenges for engineering research, for the normative suggests that we need to espouse certain values and this detracts from the logic of design.

Keywords: descriptive, prescriptive, normative, methodology

1 INTRODUCTION

The development of design methodologies is an important part of engineering design research. These methodologies can serve several purposes. We can explore these purposes by categorizing them as descriptive, normative or prescriptive. Descriptive models merely describe what is observed. The idealized form sees the researcher as a "fly on the wall", observing how design is carried out in particular contexts. The researcher does not participate in the activities and all judgment is withheld. Normative purposes seek to improve the design process and speak of how a design *should* be carried out. Prescriptive models speak of what must be done. This type of methodology demands that the designer conform to a fairly well defined model. Prescription also alludes to inevitable consequences or necessary outcomes resulting from the method.

Given a particular methodology, one might seek to determine what its purpose is. This is not necessarily a straightforward task, for the methodology may have features of more than one purpose. According to Vermaas and Dorst [1], such is the case with Gero's Function-Behaviour-Structure model of design, for they see it as having both descriptive and prescriptive features. Galle [2] extends the critique further and notes that Gero's method speaks of a product as if it exists, yet the very act of being in the midst of the design process means that the product cannot yet exist, for design precedes product.

The claimed ambiguous purpose of the FBS model presents several issues. If the boundaries between the three purposes become blurred, to what extent does that change the legitimacy of the method? Is it necessary that a method be one or the other? If the purpose is ambiguous, can we assume that there is a "problem" with the method as presented?

2 WHAT IS "BAD" DESIGN?

Any study of design, regardless of its purpose, assumes some definition of design. This definition helps us identify a likely candidate for a study of design. When conducting the study, it tells us what to look for, helps us determine what's important, lest we find ourselves having to sift through piles of potentially useless data. Hence, we must be knowledgeable of design. The definition also tells us where to begin and where to end the study, for if we hope to develop a methodology from the study, a method demands that there be a beginning and an end, even if loosely delineated.

Having identified a design context for study, we endeavour to pay close attention to what is going on. If our aim is to develop a descriptive model, we make our observations but make no attempt to interfere with the process. This, however, is not enough, for as Vermaas and Dorst [1] point out, descriptive studies must involve cases of both good (successful) and bad (unsuccessful) design; their critique of Gero is that he only used examples of successful design, giving the model prescriptive features. It is as if Gero saw the success of the design before its completion, in much the same way he makes reference to the product before the design is complete.

The inclusion of examples of unsuccessful design within a descriptive design model is not without problems. I may begin studying a process which I have determined to be design, but later find myself investigating what appears to have become something else. Is this then an example of bad (unsuccessful) design, incomplete design, or a process that should never had been considered design in the first place?

Part of the difficulty is that "design" has positive connotations and the idea of "bad design" is itself at least partially problematic. To engage in design is to engage in a positive endeavour (although the outcome may pose serious ethical or moral issues). When confronted with the concept of bad or unsuccessful design, it is not just a question of what constitutes success, but of what constitutes design.

3 THE "SCIENTIFIC" MINDSET

According to Reich [3], research in engineering design must exhibit "scientific soundness" (p. 207), or at least if one hopes to publish one's findings in a certain journal. We might therefore ask if research where the descriptive and the prescriptive are not clearly delineated exhibits "scientific soundness". Perhaps we need to preface this question with another: What is "scientific soundness"? Reich refers to "acceptable scientific means", and two world views: one where methods that are demonstrably beneficial in "real cases" and the other where methods that are "coherent". "Real" hints of description and "coherent" suggests some form of prescription. Can we mix the two world views and remain scientifically sound? To try to answer the question, I would like to back up a few more steps and consider how engineers take up the word "science".

When engineers tell the story of science, they do so in a positive light. They often begin with the work of Galileo. Galileo, we are told, exemplifies the importance of accurate description in science, for the model of the solar system that Galileo promoted was seen as being more accurate than its Ptolemaic predecessor. The model was also simpler. This combination of greater accuracy and simplicity implies that the newer model was more "true" than the older; the newer captured something the older did not. The science, however, was incomplete, for Galileo offered no explanation as to *why* the planets should follow the particular paths.

The explanation came later through the work of Newton. He explained the path of the planets with the concept of gravity. This became known as one of Newton's laws. The use of the term "law" is significant as it unambiguously points to prescription. The prescriptive model can perhaps be exemplified by considering a high school chemical experiment. If the student follows the method, the outcome is virtually guaranteed, *e.g.*, the litmus paper turns blue. If the expected result is not observed, the fault is assumed to lie not with the law itself, but with the way the method was carried out or with the equipment used to make the measurements.

Galileo and Newton thus demonstrate the importance of description and prescription for the scientific approach. But they also demonstrate something more, for one can't help but notice that both the descriptive model of Galileo and the prescriptive model of Newton were expressed in mathematical form. One might further surmise that questions regarding the distinction between the descriptive and the prescriptive can be sidestepped when one's work is contained within mathematics.

The blurring of the boundary between description and prescription is also evident in other matters scientific. Kuhn, for example, tells the story of the "discovery" of oxygen [4]. Early scientists trying to understand combustion had isolated what they called "dephlogisticated air". They could not identify the gas as oxygen (as we now know it), for there was no theory which called for its existence; no amount of observation would bring it into existence. It was only after Lavoisier developed his new combustion theory that scientists were able to identify this isolated gas as oxygen; the theory *allowed* them to see or, alternately, told them *what* to see. Description becomes possible with reference to a theory. And theory, once accepted, takes on prescriptive roles.

The story of Lavoisier also speaks of another virtue of science, namely that of *method*. We know what Lavoisier did, why he did it, what the outcomes were and how they pointed to new directions of inquiry. Method gives us assurance as it speaks of logic and repeatability. Furthermore, a fully developed method, in its idealized form, leaves nothing overlooked.

The movement from Galileo to Newton and on to Lavoisier also demonstrate that feature of science we commonly call progress. Old theories are modified or replaced when new theories show a stronger correlation between observed and the values predicted by the model. The new is an improvement over the old. The old theories are quickly removed from the canon. By keeping the canon "up to date", science presents itself as being on the "cutting edge".

The early dismissal of superseded theories allows science to maintain its authority for some of the earlier theories now appear rather naïve, for to progress means you didn't get it right the first time. Alchemy is no longer taught. By maintaining its authority, science becomes self-policing, and the validity of scientific theories is determined with reference to science itself. This distancing from the older theories creates some difficulty with the term "bad science". Due to its mode of operation, science is seen as inherently good. Thus, the term "bad science" must necessarily mean "not science". Even "outdated science" is "not science".

The constant modification or changing of theories means that science itself is undergoing some form of change. Theoretical shifts were accompanied with ideological shifts as well. Early scientists saw science as being separate from technology. Technology gradually became more closely associated with science. This was perhaps inevitable, for as scientists "dug deeper" and their theories became more sophisticated, the basic human senses could no longer provide the "raw data" they so highly valued; technology became necessary if they hoped to extend their senses. Now we take it for granted that scientists will use technology within their experimentations.

Pragmatic ideologies also forced a change in science, for science had to be put to "good use". We now associate many gadgets with science regardless of whether they are actually used within science. It is here, too, where science begins to take on a normative character, something not immediately evident in the stories of Galileo, Newton and Lavoisier. Indeed, it is due to their disinterest in the implications of their work that we bestow upon them the virtue of objectivity.

If we wish to get a stronger sense of what the normative side of science looks like, we might turn to medical science. In fact, medical science shows a strong descriptive and prescriptive side as well. Scientists can, for example, describe the state of a lung suffering from cancer. From the prescriptive perspective, scientists develop a causal link to smoking (despite the lack of studies with randomly assigned participants). The normative step comes into play when scientists say that one should not smoke. As normative, there is no guarantee that the non-smoker will avoid lung cancer; normative seeks to improve the situation, i.e., reduce the risk of lung cancer. The normative is also evident in a much more general sense in that the world is not the way it should be: we need to get rid of disease.

The medical example also highlights how the normative is quite distinct from the descriptive and the prescriptive. The normative assumes a value. The value in this case is that cancer is *bad*. Had one assumed that cancer was good, the normative view would shift drastically, whereas the description and prescription of cancer would likely remain unchanged. The normative stance thus interrupts claims of value-neutrality.

The concept of value also speaks to how method relates to a normative framework. We can readily think of method within description (*e.g.*, fit data points to a mathematical equation) and prescription (*e.g.*, use a causal model), but method with the normative is more challenging. The difference is perhaps that, unlike the others, the normative is context-dependent; Newton's universal gravitational constant hardly speaks of a context. And it is the context that also allows us to assign value.

4 FROM SCIENCE TO DESIGN

As engineering researchers began to investigate design, they brought their familiar analytical tools to bear on the new domain as there was little else to draw on at the time. Mathematics and science were the tools of choice. In keeping with the grand narrative of science *à la* engineering, early research focused on description in mathematical form and developed Computer Aided Design (CAD) tools. This, the researchers reasoned, would help engineers in their design work. These geometry-based tools grew in power and popularity with the advent of low-cost, high-speed computers. The descriptions became more complex with the paradigmatic shift to solid modelling. The previous standard described artifacts in 2-D format; the new standard stores descriptions in 3-D models from which 2-D projections are generated. In contrast to scientific descriptions, these descriptions are typically of items which do not exist. Furthermore, no grand theory is needed as virtually *any* object can be drawn within the Euclidean space.

With CAD tools well established, it was becoming evident that engineers needed additional design aids and researchers began to study the more synthetic activities of design. The subject matter of research was not so amenable to mathematical formulations and researchers turned more to science. Science can be applied in two ways. First, science can be used to study design; the idea here is that design be properly examined. Second, science can be used as a framework for the design methodology developed; the idea here is to ensure that the methodology leads the designer down a logical path and, as a consequence, a sound product is produced. Either approach might qualify for "scientific soundness"; indeed, the two are often blurred for if one insists that the study be carried out in line with science, then one would likely also insist that design be carried out with the same rigour.

One of the early assumptions of design was that it could or should be modelled as a process. Perhaps this assumption arose out of close proximity to other engineering processes, such as manufacturing. The process was broken into a series of steps, beginning with a need or problem statement and ending with the finished product. Later models recognized that the process was not strictly linear, for designers frequently loop "backwards" as knowledge from the later stages of designs informs earlier interpretations. The scientific mindset nevertheless strove to view the process as a logical one, for what else but logic could lead to such a high-performance product? By adhering to science, the logic which produces the seemingly immutable laws of science can be the same logic which leads to the perfectly functioning engineering product. However, the logical formulations can not be strictly descriptive. In decision-making, it has been found that people often violate the principle of transitivity [5]. In engineering design terms, if a designer considers the automobile to be superior to the motorcycle, and the motorcycle superior to the bicycle, then the transitivity principle states that this designer must necessarily consider the automobile to be superior to the bicycle. If the designer violates the transitivity principle, as would seem quite possible, then the bicycle can be viewed as being superior to the automobile. Such a violation would seem illogical. Thus, any assumptions of logic in this case would warp the description of the design process. Any logic assigned must be prescriptive.

Situations like the violation of the principle of transitivity present significant difficulty for researchers. Should they include the "illogical" approach of perhaps some successful design in their method? It wouldn't seem right to have a method where the causal trail is lost. Perhaps this lack of logic is just an anomaly that can be ignored, or a case of "bad" design or "not" design mixed in with the real thing. The idea of "not" design is appealing as this allows for considerable ambiguity between the descriptive and the prescriptive, for mismatches are discounted. Like Lavoisier's theory, engineers' predisposition to logic causes them to see design in a particular light.

The strong value engineers place on logic is closely linked to the preference of mathematics in solving problems, for nothing embodies logic like mathematics. And just as in our brief foray into the history of science has shown, the boundary between the descriptive and descriptive is often blurred. I first encountered this in my own research where I interviewed fourth-year mechanical engineering students at a large Canadian university during the 1990s. The conversations revealed that a great deal of ambiguity existed among students as they struggled with the concepts of prescription and description as related to the use of mathematics in engineering [6]. This confusion could well continue into the workplace. Structural engineers, for example, are found to display a kind of "skeptical reverence" to mathematics [7]: "skeptical" suggests a more descriptive viewpoint, and "reverence" a more prescriptive.

A similar kind of blurring can also be seen when we consider language. Language is often used as a metaphor for design: components are the words, and functions are the meanings of the words. Assemblies are sentences and the "logic" which tells us how those parts might fit together is grammar. Within language, we often speak of the "rules" of grammar. These rules are, initially, descriptive: researchers study how speakers of a particular language put words together to create meaning. Once these rules are formulated, they are brought back to the classroom and presented to students. Unfortunately, the rules are not presented as descriptions of what was observed; students are told, implicitly or explicitly, that they must follow these rules if they wish to speak correctly. In some ways, the cause and effect are reversed: initially, the way people speak is the cause, and the rules of grammar are the effect; later, the rules are the cause and “proper” language usage is the effect.

The reversal of cause and effect suggests that Peirce’s deduction/induction/abduction triad might offer a few additional insights. We can liken deduction with the prescriptive, something that is necessarily so. Description parallels induction, for the rules come from describing a series of cause/effect (case/result) pairs. By elimination, normative parallels abduction. Abduction is generally how we have come to understand the way design works, for we know the end result (the function) and wish to determine an appropriate starting case (the product which will necessarily have the desired function).

We would therefore expect design to have a strong normative purpose. Indeed, such would appear to be the case. Engineers create products which did not exist before and introduce them into the world. This implies a belief that the world is not the way it ought to be; it should be otherwise. This parallels the case of medical science mentioned earlier: the world is full of disease, and we believe it should be otherwise.

Engineers often have an aversion for the normative for it, like abduction, speaks of uncertainty. There is a great deal of comfort to confine oneself to the descriptive and the prescriptive and develop (logical) methods within the framework they provide. The strong normative character of design would suggest that descriptive or prescriptive methods on their own are incomplete. The fault tree analysis, for example, maps a series of possible (negative) events in a logical sequence complete with its own AND and OR gates. Yet it's the normative that decides what to do with that logical structure. The normative is where we attempt to answer the question, So what?

Researchers in engineering design has entered the world of the normative in a more direct fashion. Engineering standards can be taken as normative, although some, such as the pressure vessel standard, have strong prescriptive overtones as there exists a pressure at which a given vessel is virtually guaranteed to explode. Perhaps better examples can be found in safety. The goal here is to reduce the risk of injury to the user of the product. Safety standards are not prescriptive as there is no guarantee that the safety measure taken will prevent injury. There existence reflects a value placed on human welfare. The standards have been shifting as our values have shifted. Some of these standards are quite recent even though the products they address have been around a long time. These standards reflect shifting values such as an increasing value being placed on human welfare. We see the former ways of carrying out design as “bad” design not because of a lack of logic, but because of a misguided value system. We can expand Design for Safety to the Design for ‘X’ series of paradigms, where ‘X’ can represent any one of a host of design concerns, such as cost, manufacturability, assemblability and recyclability, to name a few. These, too, are normative in character, as they each reflect a particular value. Designers will only use these approaches if they share the values they embody.

One of the “shortcomings” of these normative areas of engineering design research is that they lack a grand narrative. There is no great all-encompassing theory. For those engineers who were raised to be in awe of Einstein’s theory of relativity, they see no glory in the normative. The normative speaks of a series of little rules, of do’s and don’ts, which, unfortunately, many consider to merely amount to common sense.

One area of normative research with perhaps a grand narrative is that of Life Cycle Analysis (LCA). This paradigm seeks to make design more comprehensive where we consider a product from its cradle to grave, *i.e.*, the point of extraction to final disposal. This approach is clearly normative as it is heavily value laden, *e.g.*, “we shouldn’t pollute”; “we shouldn’t waste”. The example of LCA suggests yet another reason why engineers may shun the normative, for it brings designers into the political arena; science has always striven to remain outside of political arena, where objectivity is seen to be compromised.

Yet another reason why engineers stay away from the normative is because engineers are trained to be product-oriented. The design methodologies are largely intent on improving the design process such that the end product is better in some way (cheaper, stronger, more durable, etc). The improvement of the product is the sole measure of the improvement of the process. But what about where the goal is to improve the process without necessarily improving the product? In other words, develop design methodologies so that the experience of design itself is better in some way. The shift in focus here is from the product to the one who produces the product. Again, this approach runs counter to what we would expect from science. How often do scientists develop new methods so that the experimenter finds the laboratory experience more enjoyable?

If researchers in engineering design need inspiration in investigating the normative, they might consider studying the approaches used in engineering ethics. Ethics deals with values and politics, and even draw on grand theories, such as Aristotle's "Golden Mean", to try and make sense of the world. There is, of course, a stark difference between the normative as I described here and the descriptive/normative discussed above: these grand theories often draw on philosophy rather than science, and often refer to very old theories, not just the new.

We finally return to the concept of "bad" design. From a prescriptive perspective, and to a lesser extent, a descriptive perspective, the words "bad" and "design" do not belong together. Having the mathematical and scientific mindset, engineers see design as a logical process and promote it as such. To claim otherwise would be to lose face in the eyes of the public. However, it must be noted that "bad" in design is not as strict as "bad" in science. Science does not generally promote the co-existence of several differing theories addressing the same phenomenon; all but one are usually eliminated. Design, on the other hand, is often quite happy to have "competing" technologies co-exist. We still have painting, even after the invention of photography; we still have movie theatres, even after the invention of videos.

In the normative world, "bad" design is an acceptable term. The normative acknowledges a value within a given context. As the context shifts, the attached values shift as well. What may be considered "bad" design in one context may be considered acceptable in another. For some, for example, the noise of a chain saw constitutes noise pollution, particularly at close range, and is a sign of poor design; for others, that sound is reassuring, particularly at long range, for it says that the operator of the chain saw is still well (silence could be the indication of an accident).

5 CONCLUDING REMARKS

Design methodologies can serve descriptive, prescriptive or normative purposes. Concerns have been raised where the purpose of a given methodology is not clearly evident. If a methodology exhibits both descriptive and prescriptive purposes, should the methodology be called into question?

As the studying of engineering design is assumed to follow in the footsteps set by the scientific paradigm, we can begin to address the question by considering how these purposes play out in science. We can see a blurring of the prescriptive and the descriptive in science as both the description of the planets orbits and an explanation of the orbits can be contained within a single mathematical equation. Lavoisier's "discovery" of oxygen provides a second example as his ability to see (describe) oxygen was contingent on the creation of a new model or theory (prescribe) of combustion.

Within engineering, mathematics also blurs the boundary between the descriptive and the prescriptive. Although one might see mathematics as strictly descriptive, the trust placed in its constructs gives it essentially prescriptive powers. Hence, to describe in mathematics is to prescribe.

Methodologies of engineering design also display the same blurring of the boundary. Descriptions of the design process typically assume that the design process is a logical process, for the product which is the result of the process, as a functionally sound device, embodies logic. However, designers do not always make logical choices, such as when they violate the transitivity principle. Some prescription is therefore necessary if the description is to remain within the confines of logic. Methodologies are not generally used to map a normative decision process; however, the normative interprets the results of the methods.

The insistence that logic be an inherent part of design suggests that "bad design", like "bad science", might be a contradiction of terms, for logic is generally considered good. On the other hand, we can recognize that, even though some parts were brought together in a logical fashion to create an object with a discernible function, *i.e.*, a design was carried out, it may still not be good. The normative reminds us that "bad design" might be the result of a misplaced value system.

Finally, this exploration raises a few questions. Science is constantly changing. As science enters the world of engineering design research, will it change, or will it come through unscathed? If changed, what kinds of changes might we expect?

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