The Role of Design in Reconceptualizing Design Science and Reconciling Innovation Processes

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Abstract

Much is known about innovation as a management process, but much less has been written about how innovation takes place as a process of knowledge formation. In this regard, Simon’s Sciences of the Artificial has been most influential, laying the groundwork for a science of design. However, it has its limits, and these limits are brought to the front whenever it has to be confronted by modern design and innovation practice. We lay out the groundwork for illustrating how Simonian thinking connects to the more contemporary modes of innovation process: user-led innovation, design thinking, and processes that invoke play. We do so by developing a basis that illustrates differences in the problem and solution spaces, in how exploratory search takes shape and in how cognition, emotion and sense-making are employed in the service of design.
The Nature of Design in Innovation Processes

Abstract
Much is known about innovation as a management process, but much less has been written about how innovation takes place as a process of knowledge formation. In this regard, Simon’s *The Sciences of the Artificial* has been most influential, laying the groundwork for a science of design. However, it has its limits, and these limits are brought to the front whenever the theory has to be confronted by modern design and innovation practice. We lay out the groundwork for illustrating how Simonian thinking connects to the more contemporary modes of innovation process: user-led innovation, design thinking, and processes that invoke play. We do so by developing a basis that illustrates differences in the problem and solution spaces, in how exploratory search takes shape and in how cognition, emotion and sense-making are employed in the service of design.

1. Introduction

This paper presents a conceptual basis for treating different innovation processes. Through the concepts drawn from design thinking and other streams of design, we form a basis for reconciling selected innovation approaches. We focus in particular on providing a common basis for discussing and reconciling design science (as construed by Simon), the more recent notion of design thinking, as well as user-led innovation, and the more creative and playful (i.e. itinerant) forms of innovating. Design methods have become extremely popular in the corporate world and business schools alike. They have been suited for addressing not only product design and other commercial innovation problems, but also as complex and ill-structured ones involving social dimensions such as public housing and the reform of school systems, though it should be noted that the practice of design will vary by the domain of interest (Buchanan 1992).

We will begin our inquest into design-led modes of innovating by examining particular dimensions that may explain differences across these modes of innovating. One of the dimensions we focus on is that of the design space. Whereas Simon looked at the problem space as a singular one, we follow the convention in design to treat it as two separate spaces: that of the problem and solution space. A second important dimension involves the manner of search (being iterative within the problem space, co-evolutionary between problem and solution spaces, or what we deem itinerant). In doing so, our premise is that certain ways by which innovation is seen to occur is particular to the domain and the manner of exploring innovatively.

Types of Innovation
Through our inquest into design-led innovation, we hope to shed light on how innovation occurs. There are also potential important implications for the types of innovation that can occur. Historically, much of what we think of as innovation seems to lie between the poles of incremental and radical innovation. These two extreme types were originally construed by Henderson and Clark (1990) to lie within a two by two taxonomy of incremental, radical, modular and architectural innovations, where radical innovation is the most extreme of innovations - one usually based on fundamental technology.

Ironically, the literature on technological innovation has not really moved beyond this typology. In part, this is due to the typology being formed from technological examples. Neither does it tell us much about the broader process of innovating, which includes...
creativity and an understanding of where to find opportunities. Nevertheless, the terminology is useful for describing the degree of innovativeness of products, even if the two dimensions are not the only relevant ones these days. We find that our notion of design needs to be situated to this debate, so as to make the concept concrete.

One more recent insight is the argument that technology results from the recombination of prior technologies. This stems from the observation that in practice, most technological innovations are themselves be created from components (Arthur 2007). While recombination can be seen as one of the mechanisms behind architectural innovation, we argue that we can go further than that. We will be illustrating how design, construed as a process that facilitates recombination, can lead to innovations. At its heart, the design process involves the mind bringing disparate structures together, such as the bringing of a structure from one domain to another. This is similar to the dominant idea of innovation in management – modularity, but it serves as a stronger basis for explaining how this modularity leads to innovations.

**Simon’s Design Science and its Limitations**

Our starting point is the design science of Herbert Simon. Simon laid the foundation for the first important conception of innovation as a design process. Simon’s view can be split into several contributions. One of his contributions to our thinking of designed systems was the idea of architectures that could be decomposed for easier problem solving. Towards the end of the third edition of his seminal *Sciences of the Artificial* (Simon 1996), Simon highlighted how the new science of complexity could encompass a theory of decomposability. This has been extended into one particular area of innovation research - the modularity literature, showing the properties under which systems can be decomposed, and hence, how innovation can be constrained, or enabled (Baldwin and Clark 2000). However, Simon also worked with an highly simplified notion of design. A number of authors in different fields have argued that Simonian thinking – including its treatment of the mind as an information processing unit, and as being boundedly rational - was constraining and even inaccurate in its depiction of actual creative behavior in real life (Bruner 1990, Hatchuel 2001, Porac and Tschang 2013). We will show that this has deep implications for the theory that emerged, and hence, the reductionist view of design that resulted.

For a long time, innovation was caught up in the linear model, which embodied the idea that innovation had to proceed from basic science towards the applied end. The innovation literature now embraces a variety of newer approaches such as user-led innovation, crowdsourcing, and open innovation (the latter two being more like organizing modes). With the advent of new inquests into innovation and innovating, our particular inquest into design being only one of many, we have reached a point where a common conceptual platform is needed for synthesizing our learnings. To develop a basis for relating these approaches, we will contrast Simonian thinking with its “design science” descendents as well as more contemporary practices such as user-centered design thinking.

We start by motivating a little why we have chosen the area of design for studying and synthesizing our understandings of innovation. Design thinking has become an important contemporary body of practice that the corporate world seeks to reinvent itself by (Martin, 2009). (Whether or not it has effectively led to the promised innovations is another matter.) There are various reasons that corporations feel the need to “shake up” their way of thinking and working, not the least being the many ways in which business can be disrupted from external influences, and the need to consider new business models involving new partners thrust into unconventional roles. Design offers a forward-looking method to quickly improve
while innovating. Unlike traditional innovation processes, which actually do not prescribe a way of working with knowledge – both the knowledge of the design (or technical) domain and the knowledge of the world, design teaches people to confront the situation, and even their beliefs in relation to it, as well as to iterate and prototype – both respected modes of work (Schrage 1999).

While design thinkers promoted their form of innovation as being “different”, innovators may also claim that design is similar to and even no different from traditional ways of innovating. Modern design thinking methods are predicated on three aspects: the in-depth understanding of users’ needs (where the needs are often ascertained through qualitative study), the iterative process, and the nature of product development. In the last, the entire cycle of the design process moves from the assessment of user needs to ideation to rough scale prototypes, and can be carried out multiple times (Brown 2009).

At the surface level, many innovation approaches may resemble design ones, in that they rely on iterative development and involve users, at least at the front end of the development process in a requirements analysis phase. The difference is that design thinking and its aspects embody certain modes of thinking, such as analogical thinking, abductive thinking, framing, and mental simulation (Garbiuo et al. 2017). These are invoked in design processes, involving alternating modes of creativity and synthesis (Kumar 2012, Brown 2009). Whether some of these forms of thinking are actually unique to design thinking (as opposed to being general forms of thinking) may be contended, so we will focus on the one that has been present in the thinking about design since the beginning: framing.

2. Design Innovation as Problem Space Identification

At its heart, Simon’s thinking on design science reduces the problem and solution space to a single design space. This conception is fundamental to how the search process is then construed, since such a problem space (say, his famed chess-playing example) has a fixed set of dimensions, which bounds the solution to a finite number of combinations of possible solution paths. “Design” then becomes the need to “search” through these possible paths. We will show that design thinking construes these kinds of spaces very differently, being at the very least about two types of spaces: problem spaces and solution spaces. This affords a much greater variety of possible outcomes.

The notion of a problem space links to another facet of design: that of ascertaining users’ needs qualitatively. Simply taken, users’ needs then become a part of the problem space, or constraints within it. We can understand this in the context of the thinking mode of ‘framing’ which we alluded to earlier. Framing was first thought of as what a designer brings to the problem, to articulate possible designs and their “fits” to different aspects of the problem (that are themselves revealed by the “solution”). Thus, there is a sequence of “moves” that the designer makes as he or she iteratively develops the idea, at each step bringing an accumulated body of experience of “design rules” to bear on “framing” the problem and its possible solutions (these being generated as temporary artifacts or prototypes of a sort) (Schon, 1983). Framing has is now more crisply articulated as a means of understanding the different aspects of a problem, and this acts as a set of constraints on the problem (Dorst, 2015). Thus, in a dialectic between the designer and user, each time the user and or designer reflects on the problem or solution at hand, they are framing or reframing what the problem is about and how fitted the solution is to the problem.
The mode of innovation known as user-led innovation is also related to the user perspective in design. However, the latter is couched as a “user as innovator” approach. This has implications for our theory, since, it suggests that the problem and solution space are collapsed into a “matched pair” (Von Hippel and Von Krogh 2015). That is, as the user comes up with an invention for him or herself, he or she creates a solution at the same time as the problem that it solves. That these users actually come up with unique solutions is in part determined by the uniqueness of the problem spaces faced by “lead users” (p.22. Von Hippel, 2005), as well as what is described as the “heterogeneity” of users’ needs (p.39, Von Hippel, 2005). The notion of user-led innovation is also tied to other more recent innovation approaches, including crowdsourcing and open innovation, where users are involved or differing perspectives or combinations of skills are brought to bear on the problem or solution.

With the popularity of design thinking, there was a preconception, fostered in part by the proponents themselves, that design thinking was intended for achieving breakthrough or never before seen solutions (in some eyes, radical solutions). However, Verganti and Norman (2014) observed that in their experiences, design approaches have more often than not led to incremental innovations rather than path-breaking ones. While there are arguments against this sort of logic, it is not the purpose of this paper to articulate a counterargument.¹ We are more interested in what conditions help design processes to become more inventive. We argue that this has to do with the amount of time and openness to experiment needed for groundbreaking design ideas to emerge. One possible condition that relates to this, and that corresponds to another important mode of user-led innovation (i.e. the designer acting as a user and not assessing other users). As Von Hippel (2005, p. 21) notes, “Although most products and product modifications that users or others develop will be minor, users are by no means restricted to developing minor or incremental innovations.” Users do this in part because they are exposed to local conditions, or in the case of extreme users seeking new experiences, such as in extreme sports, desire to heavily modify their equipment to create such experiences.

It may be that user-led invention succeeds because users are less constrained by what they feel they cannot or are not allowed to do. If so, then this relates to another emerging stream of thinking that we term “playful invention”. Play and invention that occurs within boundaries that make it “safe” to take risks and have ideas. As with inventors, designers who feel free to incubate and experiment with ideas, as well as to learn from experience, are more likely to arrive at novelty (Grant, 2017).

2. The Design Space for Innovation

Applying design and iteration between problem and solution spaces
The logic laid out in the last section can be furthered by suggesting that incremental innovations are not determined by the user-centeredness of the design process, but rather, is determined more by the nature of the search process. For instance, a search process (or environment allowing it) that gives the designer the freedom to experiment and take risks, or to willingly engage in the kind of recombinative activity that is less circumspect and more

¹ This claim can be made on two grounds, corresponding to but not entirely based on their logic: one is that design around the user can often be conflated with usability, and this by itself may steer designs to the familiar as opposed to the novel. The second is that the more inventive designs are actually created by more fundamental technological inventions, such as those invented in research labs.
playful or risk-seeking, can have profound implications for whether the innovation ends up incremental and mimetic, or much more than incremental.

This presumably works because the process identifies problem spaces which customers have not thought of before. That is, ones where the customers would not have preconceived notions of (and therefore, that may or may not exist in the customers’ eyes). Given this situation, there are lots of iterations to make sense of and learn of the customers’ preferences and needs from various prototypes (loops between problem and solution spaces, as conceived in sections 3 and 4).

3. Problem Spaces (PSes) and Solution Spaces (SSes)

Having taken a little detour to better understand the role of users in design, we now return to showing how the nature of the problem and solution spaces in combination with the search process facilitates particular outcomes for design-led innovation. We will also illustrate how these differ from the processes followed by the other modes of innovating.

Conventionally, innovation is couched as a search process which is generally described as either explorative or exploitative (Levinthal and March 1993). This model of innovation assumes that innovation is a discovery process, to determine the exact problem that needs to be solved, as well as discovering the actual solution from the universal set of possible configurations, say of technologies. A whole subfield treating this search process as hill-climbing algorithms and landscape models has emerged. In perhaps the first of these schemes, the classical Simonian chess example can be represented as a naïve search in a simplified but fixed dimensional problem situations. While he was the first to discuss the topic of the problem-solving process in a rigorous, systematic manner, at the same time, as we noted, Simon presented the situation in a highly reduced form.2 In the case of the chess board, Simon deals with a heavily constrained problem space which is the space of moves on a given 10x10 board, given all the possible strategies. However, by selecting on these dimensions for tractable computational forms of problem-solving, he was artificially constraining his problem spaces to be narrowly construed. He did this in part because of the way he thought of chess moves as a set of combinative outcomes, and this allowed for “brute force” computing to replace the mind, such as by searching through the “list” of all possible combinations. Simon does cite other examples such as architecture as embodying more creativity, and as having a more flexible set of parameters that lead to more inventive designs. Simon’s thinking actually seeded the emerging design science, but despite the hamstrung manner of the problem situations his approach posed, he later recognized the possibility of emergence.3

One element missing from this picture is a mechanism that describes how recombination can occur. We know from creativity and cognition studies that blending is a powerful mechanism, perhaps as foundational as analogical thinking. A parallel was drawn by Arthur (2009) for

2 Simon actually posed problems that were defined in a highly-constrained fashion, in part due to the computational methodology and computational theory of human problem-solving that he was proposing to use for solving such problems.

3 In the third edition of The Sciences of the Artificial, Simon discusses a parable of Horus and Tempus, which describe the two ways in which watches can be made: a top down design process or a bottom up design process. Hidden in that parable, however, and that illustration of design science, is that the design has to be about a certain specification of architectural form that fits to a given purpose of function and aesthetical requirement. If we assume that at the beginning, those purposes that form “fits” are unknown, then, that is what we defined as the problem space.
technological artifacts in the conceptual and physical world when he created an understanding of technology as having its own motive forces, supplied by science, which is eventually embodied in individual components. Up to this point, he shares the same roots as Simon and the modularity literature. Where Arthur deviates from modularity is when he seeks to create an evolutionary view of the impulses that allow new technologies to emerge from the recombination of technological “primitives” (i.e., basic modular components). In it, he shows how the various combinations can lead to many possibilities, all less unrestricted, since some of those combinations take place across domains. Thus, in effect, technological functions can be reapplied across domains to create new functions or meanings. Arthur does not say much about problem spaces, but he leaves open the idea that there are uncountable such problem spaces, all possible due to our ingenuity to explore for them all.

What Simon Says, and Doesn’t Say (About Problem Spaces)
Given how constrained Simon construed his “problem space” to be, we posit that there is still much to left to be said about problem spaces, especially when we start to think about design spaces that are much more open-ended. We argue that we need a more expansive definition and typology of problem spaces to help account for different modes of innovating. The design method is considered to be well-suited to exploring ill-structured problems, that is problem spaces that are undefined and that do not have neat solutions (Buchanan 1992). Typically, designers will entertain the broadest PS possible (called the “design brief”) from the client, but this itself is more like an umbrella that can include many possible PSs (e.g. each one can being formulated around a user’s particular needs). For instance, in a design thinking approach, each time the user is interviewed on their needs, and each time they surface a new need, be it functional or emotional, a new problem space is created. Each of these varies on a completely different conceptual dimension than the others.

We can see how far we need to deviate from Simon’s thinking by looking at his description of the most expansive type of problem space that he entertains – that of the example of an architect designing a house:

It will generally be agreed that the work of an architect—in designing a house, say—presents tasks that lie well toward the ill structured end of the problem continuum. …The design task (with this proviso) is ill structured in a number of respects. There is initially no definite criterion to test a proposed solution, much less a mechanizable process to apply the criterion. The problem space is not defined in any meaningful way, for a definition would have to encompass all kinds of structures the architect might at some point consider (e.g., a geodesic dome, a truss roof, arches, an A-frame, cantilevers, and so on and on), all considerable materials (wood, metal, plexiglass, ice—before you object,… (Simon 1996)

In contrast to the fluid types of “aesthetic design” problem space that can cross many conceptual dimensions, each creating another problem space, it appears that Simon envisioned a single problem space, whether it was “designing a house” or “finding the winning chess strategy”. The process of “designing a house” may thus involve templates, effectively narrowing the solution space down to a set of standard architectures and components. Thus, while the architect’s problem space appears by Simon’s estimation to be a more unbounded one than his chess example problem space, it is actually still bounded and “closed” by the user’s or buyer’s expectations (i.e., what a house should look like) and the number of candidate solutions (i.e., what houses have to look like, in order to not defy the laws of gravity, weather, etc.). In other words, Simon refers to the problem space in terms of
the components needed to put together the house, but he neglects to mention where the real problem space lies: the idea of a house and the aesthetics it provides to its occupants or viewers, and how the house should function. In reality, architects follow market and user expectations of what a house looks like. It is because of this “social construction” (i.e., societal expectations) of a house that we end up with a limited view of what houses should look like. All houses look the same – with an inverted V shaped roof (to allow water to run off), four walls on each side of a room, a flat ceiling, etc. There are variations, but there are reasons for these arrangements (e.g. the flat ceiling accommodates an attic, which provides more space).

The question then is, under what conditions does this conventional kind of thinking about houses get challenged, resulting in extreme designs for “houses”? There is a special case of less-constrained PSES that occurs when there are unusual physical constraints that designers have to create extreme designs for. This “permits” more variant styles of architecture or consumer acceptance of the same). The reason why this represents a loosened constraint (or more loosely bounded) version of Simon’s earlier architecture example’s PS, is because we can admit other possibilities outside of standard expected solutions. When the space (or PS) the architects have to design for is “unusual”, it is say to assume that consumers will not expect “the norm” in solutions. When consumers expect the unexpected, architects are released from consumer expectations, and there are possibilities for avante garde solutions that do not look like most houses or designs. An example of this is Frank Lloyd Wright’s Fallingwater, where the idea was to allow the waterfall’s natural course to be untampered, so that it was allowed to course through the house. Another such special case of a geographically constrained problem space requiring the loosening of what a house should look like are unusually shaped parcels of land. Examples of such extreme solutions of unusually-shaped homes made for odd spaces are also found in space-constrained areas like Tokyo, where houses with narrow footprints look much taller than their ground area, or one designed to spread over narrow snake-like plots of land.

Thus far, we have been talking more about the “resistance” of social expectations to the novel. This is in part why user-led innovations tend to come from extreme users – their expectations from their experiences are far from the normal, and they have a higher tolerance for the unusual.

In this section, we started by talking about problem spaces, but the discussion eventually moved towards the search for solutions, since the user expectations in effect define the space of acceptable solutions. Within the search for solutions, the general mechanism by which designs come about in the engineering fields can be modeled by Arthur’s description of innovating as the recombination of simple technological modules and their functions. In the teaching of engineering as a design science, engineers working in the systems tradition are taught to construct products by working with these variant functions of modules, so that different ways of achieving those functions through component recombination can be considered. This advances the discussion of designing beyond Simon’s description of problem-solving as a search or discovery process. We will now turn to the final piece of our framework: search process and the manner in which different problem and solution spaces are “searched”.

4. Design as Search that Traverses Both Problem and Solution Spaces
We are now in a position to introduce search - the critical dimension that binds the previous elements together. We have discussed how the aesthetic design traditions such as design thinking approach the issue assuming there to be many possible problem spaces, each defined anew by users’ preferences, or their expectations for the unusual. That is, there could be as many sets of problem spaces as there are users, since each user can have a different set of needs.

Another critical aspect of design thinking is the design process involves iterating between both the problem and solution spaces. In design thinking or other similar design traditions valuing the open-endedness of the solution, the problem space is allowed to change, given new information on the user and his response to the designs (or new users even!).

The typical design thinking approach involves a process that moves stage-wise from empathy (determining user needs) through to ideation to prototyping and validation. Iteration is promoted between stages of the process so that when new information changes circumstances, for instance, the designer can take the steps to adjust the design principles or design itself.

**The co-evolution of PS and SS seen in design**

Another framing of the design approach suggests that the designer actually iterates by alternating between the discovery of new problem spaces and invention of solutions to them (solution spaces). In the design literature, PS and SS are said to be co-evolving (Dorst and Cross 2001). How this happens in practice may vary. For instance, in human-centered design, different user needs are uncovered as different iterations are used to learn or probe into users’ needs or reactions to the designed interventions (represented as artifacts). New PSes are revealed as more is learnt about the users’ needs and wants, or as more users are encountered. Rough prototyping methods are used early on in the process to help not merely to validate (as occurs in engineering), but for the designer learn more about the users’ needs from their responses, and to help the designer to find a more promising problem space based on the new needs that were revealed. This mechanism alone can help design achieve more inventive solutions, which are defined as “new to the users’ experience”.

In practice, what many designers may do is reframe the problem space slightly so as to iteratively create a better-fitting solution for an externalized user (often externalized as a persona built on user data). More inventive solutions may occur if the designer or team brings new knowledge and perspectives into the process, or if an extreme or lead user is studied. Without this, if the learning is always centered on the same user providing feedback to the designer (presumably in more depth each time), the process can become convergent, and possibility lead to incremental innovations.

**Traditional Circumstances and Special Cases**

We will now turn to examine three cases that do not “fit” with this story of the co-evolution of PSes and SSes. One is the traditional engineering approach, the second is that of design processes that lead to incremental innovations, and the third is that of the user-led model, where there is no external user, but rather, one where the designer “internalizes” the user by acting as the user and designing for oneself.

**(1) Traditionally Convergent “Iteration”**

Iteration is also quite common in traditional engineering situations, but it is usually only iteration within the specified problem and its solutions, and not between the problem spaces
and solution spaces. What typically happens in such fields as traditional engineering is that, after the requirements analysis phase, and the selection of a design, the process specifies a single product that is increasingly detailed as its development proceeds (any broader conceptual changes in the product’s architecture or type would have taken place at the early stage or front end of the process, known as the “fuzzy front end” in new product development).

(2) Expectations of the Mundane
Now we return to Norman and Verganti’s view that design was (from their experience) by nature incremental – with for instance Norman noting that the human computer interface design work he knows that employed user-centered design methods always led to incremental innovations. We argue that this may be due to his working in a design field the emphasizes usability above all else. The dominant emphasis for products such as user interfaces almost always predicates usability over inventiveness, and new user interfaces based on new forms of interactivity simply do not come about easily, other than through research. Thus, most of what goes for innovation is actually surface level “search” for more pleasant placement of or accessibility to information on screen.

In general, as we pointed out with Simon’s example of the architect, if designers are designing for mundane expectations or purposes (e.g. shopping carts) or pragmatic users, then the more exotic and interesting designs may never arise. This is theoretically framed by Moreau and Engeset (2016), who noted that ill-structured PSeS are not supported by aspects of well-defined solutions (SS), or what we might term aspects of structured search processes.

(3) Von Hippel and Von Krogh’s Need-Solution (Matched) Pairs
We now turn to another special case of a search and PS. In certain design fields or situations, the product cannot be understood until a prototype is produced and experienced. Videogames are one example of this. These are what Von Hippel and Von Krogh (2015) call need-solution pairs, or what we call matched pairs (i.e., PS and SS are one and the same).

In design situations such as those seen in product, architecture or games, during the invention process, the problem (i.e. framing) is articulated only at the moment or just after the solution is articulated. If the designer is not consciously designing to some previously articulated user’s need, the designer has to be designing to “their” need or to a freely articulated need. For instance, in game design, the designer is designing the game he or she wants to play, but she only knows it at the moment that idea is created. There is no “user problem space” because there is no user. In this search mode, ideas automatically solve a problem that they were raised to solve/were matched to. It may be because the designer is already solving a problem that he or she felt to be the issue (as a user). This mode of user-led innovation is often employed in design domains were the designer is an expert and is inventing something they find interesting, e.g. games, or product design where the designer is not thinking of external users, but perhaps of themselves as users.

In this schema, even though it is a design schema, it is not a design thinking one in the sense of finding out about another user’s needs. Instead, the designer himself is the user. In this way, there is no external problem space (of a user external to the designer) that needs to be “discovered”. The design process may still involve iteration, as with happens with game design, but it is centered on the designer as the user.
We have introduced the concept of iterative search, but talking about search without the human element is to consign it again to the information processing paradigm that we wanted to move away from. In this day and age, it is an even more dangerous, as it predicates automation above the human mind, and it fails to recognize human qualities and faculties that are special. We need to have a model of search that illustrates how human qualities come to bear. Knowledge workers intuitively know this, as there is something about how they “process” and combine information, involving and invoking different perspectives, that cannot be duplicated by computers yet.

Some indication of this is also seen in the design process, as design thinkers often predicate qualitative knowledge over the quantitative (statistical), something computers are poor at creating and dealing with. Design tends to emphasize the seeking of user’s needs through expressed emotions, where emotive responses betray users’ deeper feelings about a situation or the designed intervention (e.g., a prototype they are reacting to), and can be probed deeper for fundamental reasons. Organizations as IDEO are known to be playful and fostering of play in their attempts to get designers to take risks and break down boundaries of knowledge (Hargadon and Sutton 2009). In fact, it is this very human appreciation of aesthetics that caused one of the chief architects of the design science literature, Alexander, who’s work on patterns rivaled Simon’s, to abandon his goal of creating a pattern language for architectural design, and to revel in the wondrous qualities of inspired designs, such as ones inspired by nature (Cross 2001).

6. Conclusions

We have laid out a series of dimensions that can be useful for understanding how and why invention takes place in various modes. They provide a deeper insight into why user-led innovation and design thinking are often thought of. They also show how design thinking shares certain characteristics with traditional engineering (e.g. iteration), but in service of a particular cause. We also showed that it is sometimes the users and domain themselves (e.g. in human computer interfaces) that make the design thinking results more incremental. This is because the user locks in the expectations. In this way it is similar to Simon’s base case example of an architect designing a house.

References


