Metaphors in Conceptual Design

Conference Paper · January 2007

DOI: 10.1115/DETC2007-34874

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Proceedings of the ASME 2007 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference
IDETC/CIE 2007
September 4-7, 2007, Las Vegas, Nevada, USA

DETC2007-34874

METAPHORS IN CONCEPTUAL DESIGN

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ABSTRACT

A metaphor allows us to understand one concept in terms of another, enriching our mental imagery and imbuing concepts with meaningful attributes. Metaphors are well studied in design, for example, in branding, communication and the design of computer interfaces. Less well appreciated is that our understanding of fundamental design concepts, including design itself, is metaphorical. When we treat design as a process of *exploration* or when we get together to "*bounce* ideas off each other" we understand the abstract concepts of design and ideas metaphorically; ideas don't literally bounce, nor are we literally exploring when we design. Our research is a descriptive study of the metaphors employed in design. It is the first phase in a longer research effort to understand the impact of design metaphors on creativity. We investigated whether design authors employed different metaphors for the overall design process and consequently for core design concepts. To address this hypothesis we analyzed the language used in the concept generation chapters of nine widely used engineering design textbooks. We coded each metaphorical phrase, such as "finding another route to a solution," and determined the core metaphors in use for common design concepts including, ideas, problems, solutions, concepts, design, the design process, user needs and others. We confirmed that authors with differing views of design do indeed emphasize different metaphors for core design concepts. We close by discussing the implications of some common metaphors, in particular that Ideas Are Physical Objects.

INTRODUCTION

"[The meeting originally scheduled for next Wednesday] has been put forward two days. To which day has the meeting been rescheduled?" This was the question put to participants in a study by Lera Boroditsky [1] to determine the effects of our conceptual metaphors for time. Although not universal, much of the world holds a common metaphor for time; we conceptualize time in terms of space. This is why phrases such as, "We're getting closer to the hand-off," and "The launch date is nearly upon us," make perfect sense to us. We use a physical source domain, in this case "space", to talk about an abstract target domain, in this case "time". In Boroditsky's study, whether participants said the meeting was on Monday or Friday depended upon whether they were primed to think about moving toward an object, or pulling an object towards them. This is because we have two common perspectives on time: an ego-moving perspective, where we are metaphorically moving through a stationary landscape of time ("We're getting closer to the hand-off"); and a time-moving perspective, where we remain stationary and events move past us ("The launch date is nearly upon us"). When primed with the ego-moving perspective participants were more likely to say the meeting was on Friday, and when primed with the time moving perspective they were more likely to reply Monday.

Metaphor use such as this is pervasive whenever we talk, or think, about abstract concepts. As Lakoff and Johnson argue [2],"…metaphor is pervasive in everyday life, not just in language but in thought and action. Our ordinary conceptual system, in terms of which we both think and act, is fundamentally metaphorical in nature." (p.3)

Table 1 provides some examples of every day expressions (for more examples see Kövecses [3]) and the metaphors that enable us to make sense of each one. In each case the metaphor is expressed as a *Target Domain* (Time, Knowing, Importance, Difficulties…) mapped to a *Source domain* (Space, Seeing, Size, Burdens…) as in Ideas Are Objects (Metaphors in this paper will be referred to in Title Case). The mapping is shown diagrammatically in Figure 1.

TABLE 1: EVERYDAY PHRASES AND METAPHORS

Expression	Metaphor in use		
	Target domain		*Source domain*
It won't be *long* now	Time	Is	Space
I *see* what you mean	Knowing	Is	Seeing
Tomorrow is a *big* day	Important	Is	Big
She's *weighed down* by responsibilities	Difficulties	Are	Burdens
Let's give her a *lift*	Happy	Is	Up
He greeted me *warmly*	Affection	Is	Warmth
That theory has no *foundation*	Theories	Are	Buildings

The target domain is the domain we are trying to understand. The source domain is typically taken from our physical experience in the world, for example, we move about in space, we see, we appreciate size, we feel the weight of burdens and so on.

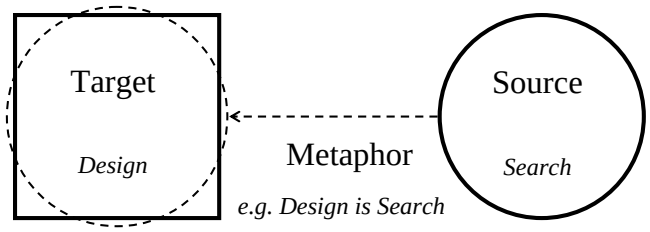

FIGURE 1: METAPHORS MAP FROM A SOURCE DOMAIN TO A TARGET DOMAIN

A quick review of the language of design illustrates that many of design's fundamental concepts are also metaphorical, for example: we need to *narrow down on* a concept; let's *bounce* around some ideas; let's *break* the problem *down*; maybe there's another *route to* a solution; how can we *resolve* this conflict?; this is an *elegant* solution; we need to think *outside the box*; encourage *wild* ideas [4]. Gabora [5] also observed that many common expressions for creativity derive from expressions relating to light, for example: she had a flash of inspiration; he's a bright spark; I saw the light; we had an illuminating discussion; and of course, the ubiquitous light bulb to symbolize an idea.

Lakoff and Johnson [6] argue that the metaphors we hold for abstract concepts provide us a richer way to understand them, allowing us to reason about them and make inferences using them. For instance, the common metaphor Time Is A Resource in effect allows us to make good use of it or even waste it. Without it time would not seem like something we could waste, and maybe we wouldn't feel guilty for that lazy morning in bed. Gentner and Gentner [7] added weight to this hypothesis studying mental models for electricity and providing evidence that our mental models of a domain, for example understanding electricity as flowing water or a moving crowd, affect the inferences we make in that domain. Identifying the metaphors in use to understand a domain then is the first step in understanding how we reason about that domain. As yet, this analysis has not been performed for design.

In this paper we address two research questions:

1. What are the common metaphors we use to structure our understanding of important design concepts and design itself?
2. How does our understanding of these concepts influence our approach to creative design?

To answer these questions we first outline a brief review of prior research and use of metaphors in design before detailing our study of design metaphors in design textbooks and presenting the most significant metaphors we observed. Given that design itself can be understood through metaphor (e.g. Design Is Search) and it, in turn, involves the core concepts of ideas, problem, solutions and more, we hypothesized that the metaphors used for these core concepts would be affected by the metaphor in use for design overall.

We finish by discussing the implications of these metaphors and putting forward several propositions for future study. The ultimate goal of this research is to lay the foundation to determine how our understanding of these common design concepts affect our capacity for creative design?

BACKGROUND

Metaphors have been studied and employed in several areas of design.

Software and Interface Design

Probably the most discussed use of metaphor is in software interface design. Common metaphors in use, such as the Desktop Metaphor, file folders, and windows, structure our daily experience on computers. Carroll et al. [8] provide a useful overview of metaphor use in Human Computer Interaction together with examples of software applications that used metaphors to drive their interfaces. Metaphors even structure our experience on the web; for example, Maglio and Matlock [9] showed how both novice and expert users understand the web in terms of space via the metaphor Information Space Is Physical Space, although we would argue that the notion of Information Space is the defining metaphor itself. Metaphors also abound in common programming

concepts for example, buffers, stacks, loops, encapsulation and so on.

As metaphor use is so pervasive in computing it is tempting to employ it whenever possible. However, as several authors have noted [10][11][12] while metaphors speed up our initial understanding of a new piece of software by referring to commonly understood physical actions, for example, cut and paste, they also hinder our ability to go further and use the full power of computing available to us. Cooper [10] gives as example, the failed suites of software that created a virtual mall to recreate the shopping experience; as one quickly finds out, traversing the distance between shops in a software program quickly becomes tedious when it is possible to head there with one click of a mouse.

Metaphors for communication

Metaphors are also commonplace within the design process as a design team works on a challenge and strives to develop a shared vision of what they are designing. Stubblefield [13] discusses the development of a *Design for Machinability Advisor*. The software program was originally envisaged as a "spelling checker" for machinability problems. The spellchecker metaphor persisted as the design progressed, enabling both effective communication and discussion about the features of the software and between different design groups. The shared metaphor provided a common understanding of the design via a commonly understood technology – a spellchecker. As the design progressed, however, it became clear that the spellchecker metaphor was not entirely appropriate for what they intended to do. For example, a spellchecker finds mistakes in a document, yet the team realized the advisor was far more useful if it would also offer advice as the design was being created. The spellchecker metaphor placed a harmful emphasis on finding problems rather than preventing them. Eventually the team moves forward by employing a dual approach – using both spellchecker and advisor metaphors. Metaphors, then, also have a social context in which they operate and can both support and hinder communication and cooperation within design teams.

Metaphors are also touted as providing a strong common goal for design teams as they struggle to overcome a technical challenge or develop a new product. Nonaka [14] illustrates how the goal of making a photo copier like a beer can – cheap to produce, lightweight and reliable – pushed the design team to develop a new type of copier with the fragile parts in the replaceable print cartridges. The Beer Can Copier metaphor provided the team with a shared goal and a common ground for communication. In 1981, Apple Computer Inc., created advertisements that employed the metaphor for a new Apple computer as a "bicycle for the mind" [15] The metaphor provides a clear goal, assists the design team in their task and communicates the benefits clearly to customers

Framing a problem

It has also been suggested by Schön [16][17], that metaphor can play a crucial role in the framing of the design situation by a design team. Schön [16] discusses an urban planning problem where the framing of a slum as either a 'blighted area' that needs to be cured, or as a 'natural community' that should be preserved, significantly changes the design situation itself. In another example, Schön [16] discusses a design team trying to improve the design of a paintbrush. At first, the team consider the paintbrush as a form of 'spreader' for the paint. A different perspective on the problem was provided by a team member who saw that the space in between the bristles of the brush held the paint and the paintbrush could also be seen as a pump for the paint. When the team reframed their problem in this way the metaphor highlighted new solution directions. Metaphor use in this way is supported by Casakin [18] who found that architecture students found it easier to use metaphors in the early, problem framing, stages of design than later.

In another example, shown in Figure 2, Kimiko Ryokai, while at MIT's Media Lab, employed the World Is A Palette metaphor to reframe the digital paint bucket metaphor in a radically new direction – using everyday physical objects as sources of colors, textures and even movements for painting.

FIGURE 2: THE I/O BRUSH EMPLOYED THE WORLD IS A PALETTE METAPHOR [19]

Branding and form

Finally, metaphors have long been recognized in industrial design and employed in the development of brands and the ultimate form of a product. The new Apple iMac was designed to evoke the form of a sunflower [20]. Lundholm [21] provides several examples including evoking animal qualities in, for example, the Jaguar brand, and the Black and Decker electric sander that employed the metaphor of a computer mouse, a "form that is non-threatening, fun, and a bit lovable."

TABLE 2: ENGINEERING DESIGN TEXTBOOKS ANALYZED

	Textbook title	Authors	Chapter(s)	Number of instances
1	Design Methods	Jones [26]	Part 2: Section 3 and 4	48
2	Product Design and Development	Ulrich and Eppinger [27]	Chapter 6: Concept generation	35
3	Total Design	Pugh [28]	Chapter 4: Design Core: Conceptual Design	34
4	Engineering Design: A project-based Introduction	Dym and Little [29]	Chapter 6: Finding answers to the problem	38
5	Engineering Design Methods	Cross [30]	Chapter 9: Generating Alternatives	14
6	The Mechanical Design Process	Ullman [31]	Chapter 7: Concept Generation	80
7	Engineering Design: A Systematic Approach	Pahl and Beitz [32]	Chapter 4: General Methods for Finding and Evaluating Solutions	42
8	Product Design	Otto and Wood [33]	Chapter 10: Generating Concepts	66
9	Fundamentals of Engineering Design	Hyman [34]	Chapter 6: Concept Generation	39
			Total:	396

Metaphors for design

While several authors, notably Madsen [22],[23], have proposed means for using metaphors in design – metaphorical design – only a few have commented on the metaphors we employ for design itself. Lanzara [24] provides a broad analysis illustrating different overall perspectives on design employing, for example, the metaphors Design Is Functional Analysis, Design Is Problem-Solving and the shift towards Design Is Problem-Setting. Yet while metaphors have been actively studied for software and interface design, communication, problem framing and branding and form, we believe metaphors for design itself, and its most common concepts, have been so far neglected. We now turn to the design of our study of metaphor use for design itself.

METHOD

Extracting metaphors from natural language discourse is the most common means to learn about the metaphors in use in a domain. Identifying these metaphors provides a clue to our conceptual understanding of a domain. Despite this common approach we found no prior references that detailed a rigorous approach to metaphor identification from natural language. The closest is Michael Reddy's seminal paper on the Conduit Metaphor [25] where he illustrates the process of collecting example phrases before identifying the metaphors at work. The Conduit Metaphor illustrates how the subtle, yet pervasive, metaphors Words Are Containers and Ideas Are Objects combine in our discourse about communication as when we say "It's hard to *get* that idea *across* to him," or "His words *carry* little meaning." We took a similar but more structured approach of surveying language in nine widely used English language engineering design textbooks. These textbooks were chosen based on their use by faculty in the engineering design community and to provide coverage in the United States, and Europe. Our approach consisted broadly of three phases:

1. Extracting instances of metaphors from design texts
2. Categorizing metaphor instances
3. Identifying underlying metaphors

Phase 1: Extracting instances of metaphors from design texts

Table 2 details the textbooks that were used in this study and the number of example phrases identified in each. Note that we include the number of instances extracted from each for transparency, yet the absolute quantities do not bear significantly on the analysis as each book takes a different approach in their discussion, with some emphasizing more abstract discussion and others emphasizing more concrete

examples. The linguistic nature of the domain makes quantitative analysis difficult if not misleading at times.

Design textbooks are a fruitful source of study as they hold some of the greatest potential to influence design teaching and culture. We confined our analysis to chapters that dealt primarily with conceptual design, including concept generation, for two reasons. First, these chapters generally contain the highest density of discussion of the more abstract concepts in design and are thus a richer and more concentrated source of metaphors than other chapters on the design process. Second, we are interested in how the metaphors in use affect our capacities for creative design and much of the creative phase of design is generally considered in this step. While creative activity can happen just as often outside of the conceptual phase, discussion of this creative activity occurs significantly less. For example, later chapters may show similar metaphors to those found in our analysis but the density of the instances within the text is much less with more discussion of other concepts such as risk or testing. In our discussion we also draw from some widely used metaphors about design to support our conclusions.

Two researchers collectively identified and coded nearly four hundred unique instances of sentences or phrases concerning design or key design concepts. A protocol was developed to enable the two researchers to reliably identify the same examples over identical sources. A test coding the same chapter from a randomly selected textbook yielded 88% agreement between the instances selected.

Coding involved labeling each instance with the associated design concepts – the Target domain of any underlying metaphor (e.g. Ideas, Problems, Solutions…). Once sufficient instances of each Target domain were identified, the researchers identified metaphors that provide coherence to each of the instances.

Table 3 shows an example of an extracted instance and the codes applied to it. The sentence refers to three distinct target domains: (1) the design concepts of ideas; (2) solutions; and (3) problems. Each design concept is referred to metaphorically. The example in Table 3 illustrates how each of these target domains is qualified in some way: ideas can be triggered off and can be spontaneous; solutions can be ready-made and produced (even if brainstorming can't do that); and problems can be complex and solved (or in this case, difficult to solve).

Many design concepts are not abstract entities; they have a very real existence. So while we can refer to a Design Sketch As A Tool, the sketch itself is not abstract, it has a very real physical form. These tangible concepts, including sketches, matrices, decisions and such, were not included in our analysis or coding scheme as their roles are more clearly understood than the abstract concepts of design ideas, problems, solutions and such.

TABLE 3: CODING EXAMPLE

Source	Instance	Codes
Pahl and Beitz, Systematic Engineering Design, [32]	Brainstorming is meant first of all to *trigger off new ideas*, but it cannot be expected to produce *ready-made solutions* because *problems are generally too complex and too difficult to be solved* by *spontaneous ideas* alone.	Ideas Solutions Problems

Phase 2: Categorization metaphor instances

Once the metaphor statements were collected we began a sorting process where we first grouped instances of the same target domain, for example, collecting all the sentences that referred to 'problems'. We then listed all the qualifying statements for each Target domain in the form 'Ideas can be, refined, polished, amassed, shared, bounced around…' The tables produced as the outcome of this phase illustrate the affordances [35] each design concept possesses.

Phase 3: Identification of coherent metaphors

The next stage was to identify suitable metaphors that explained as many of the instances as possible. This phase was conducted as a series of clustering steps, in each step gathering together affordances that highlighted similar properties. For example ideas can be handed to other team members and can also be bounced off them. Both of these affordances support the metaphor Ideas Are Physical Objects.

In almost all cases each Target Domain was mapped to several different source domains depending upon the context of the statement, for example, Ideas are seen as both Food ("I need some time to *digest* what you said.") and Products ("This idea needs to be *refined*.") Several metaphors, including Ideas As Food and Ideas As Products, supported the metaphors identified previously in the literature (for example [2],[6]). Once metaphors were identified we analyzed the implications of the use of each metaphor in design.

RESULTS

In this section we identify the most frequent metaphorical concepts employed in the design texts, as well as the most frequently used metaphors for each concept we found.

Metaphorical concepts identified

We grouped the metaphorical concepts referred to in the design textbooks into three categories sorted by frequency of mention: Universal, Often and Occasional. Universal design concepts included references to design itself and the design process, ideas, concepts, problems and solutions. Concepts

seen often on our analysis include user needs and design tools or methods. Concepts mentioned occasionally include design conflicts or trade-offs, design principles, and references to creativity. All of these concepts are the Target domains for our subsequent analysis; they are the domains that we are trying to understand. The universal and often mentioned concepts, and their frequency of occurrence, are shown in Table 4.

TABLE 4: COMMON METAPHORICAL CONCEPTS – TARGET DOMAINS

	Target domain	Frequency
Universal	Ideas	86
	Solutions	80
	Concepts	72
	Problems	64
	Design	57
Often	Design Tools or Methods	12
	User needs	9

Metaphor instances and mappings

We followed a process of grouping each of these affordances in the instances we coded to help determine the metaphors in use for each target domain. Below we present the results of the analysis in the form of a metaphor in use, together with the affordances that led to the identification of the metaphor. We begin with the virtually universal design concepts, Ideas, Problems and Solutions. For each affordance listed below we extracted at least one instance of it in use. In some cases such as "Ideas can be *generated*," examples were so numerous at some points they were present in almost every sentence.

Problem Metaphors

- *Problems Are Puzzles:* They can be solved and resolved.
- *Problems Are Locations:* They can be explored, be open-ended, approached, have boundaries, points of entry and we can define a problem space.
- *Problems Are Gaps:* There can be "unsatisfactory gaps in a problem space," we can require a creative leap.
- *Problems Are Objects:* They can be assembled, viewed from a different angle, divided, decomposed, be hard, big, well-structured or ill-structured, transformed, patterned, complex, broken down into sub-problems, refined, clarified, broken into parts, and stable.
- *Problems Are Formulas:* They can be formulated, underdetermined, ill-defined and require an answer.
- *Problems Are Obstacles:* They can be barriers between a present state and a goal, be side-stepped or hurdled.

Solution Metaphors

- *Solutions Are Living Entities:* They can come to you, emerge, appear and have origins.
- *Solutions Are Children:* They can be born and embryonic.
- *Solutions Are Locations:* They can be arrived at, approached, defended, attacked, in a direction, in a space, you can find a route to them.
- *Solutions Are Objects:* They can be sought, discovered, absent, existing, overlooked, in fragments, divided into categories, integrated, found, provided by something, handed to someone, in your mind, purged from your mind, in parts, combined and manipulated.
- *Solutions Are Products:* They can be produced, ready-made, useful, generated, rough or polished.
- *Solutions Are Resources:* They can be yielded by a search space, meet a need, suggested by analogy, for a specific problem, of a problem, to a design problem, match a design problem, optimum.

Idea Metaphors

(We observed that the word 'Concepts' is used almost interchangeably with ideas)

- *Ideas Are Living Entities:* They can emerge, come, cannot be forced, and they can be spontaneous.
- *Ideas Are Children:* They can be embryonic or killed.
- *Ideas Are Explosives:* They can be triggered off.
- *Ideas Are Liquid:* They can flood and flow.
- *Ideas Are Locations:* They can open new paths, lead to a solution, or be a range.
- *Ideas Are Objects:* They can hit the bull's eye, be created, judged, generated, accepted, integrated into the process, scrutinized, associated, criticized, possessed, combined, hit, bounced, sorted, found, and amassed.
- *Ideas Are Products:* They can be developed, modified, amended, changed, adapted, produced, fragile, improved, debugged, repaired, refined, useful and manifested.
- *Ideas Are Resources:* They can be a match between a problem and a solution, and exploited.

Design Metaphors

Overwhelmingly the most common metaphor we identified for design derives from the Information Processing perspective of design [36], that of Design Is Search.

Consider the following example phrases taken from different textbooks:

"It will prove particularly helpful in *finding* a first solution concept as a *starting point* for further variations. It must, however, be said that this *approach* carries the danger of causing designers to stick with known solutions instead of *pursuing new paths*." [26], p.74

"Such an approach allows full *exploration* of the *design space* and reduces the chance of *oversight* in the types of solution concepts considered. It also acts as a *map* for those team members who are less experienced in design problem solving." [27], p.120

In these examples a 'design space' is laid out in which we start at some unsatisfactory location and we wish to navigate towards a satisfactory location, a solution. Several variations of the design space metaphor were also commonly identified including Design Is Exploration, Design Is Selection (among paths in the design space) and Design Progress Is Reduction of the Search Space.

Other metaphors for design were also seemingly able to coexist with the Design Is Search metaphor. These included Design Is Decomposition and Design Is Problem-Solving. The Design Is Decomposition metaphor takes a more physical view of the design situation where a problem can be decomposed into sub-problems or functions for which solutions can be found and a final solution can be synthesized from these 'solution fragments.' The Design Is Problem-Solving metaphor, by contrast, is typically associated with a view of Problems Are Puzzles or Formulas for which a solution can be inside or be the key to unlock it or an answer. We also note that other authors [37], not in this study, have proposed Design Is A Journey with the Designer Is A Traveller.

Design was also universally seen As A Process. The process typically contains steps, stage-gates and iterates in a cycle.

DISCUSSION AND CONCLUSIONS

Our discussion is organized around four themes: different views of design, different core metaphors, universal metaphors and specific implications.

Different views of design

We found that different authors do indeed emphasize different approaches to framing the design process. These different views are reflected in the metaphors they use for design and the design process itself. Textbooks adopting more systematic approaches to engineering design typically employ both the Design Is Search and Design Is Decomposition metaphors with different emphases on each. We stress once again that the Design Is Search metaphor was pervasive in almost all sources we analyzed.

The pervasiveness of the Search Metaphor for engineering design is an interesting contrast to more people-centered approaches as put forward by researchers such as Bucciarelli, Rittel and Schön. Both Bucciarelli and Rittel choose metaphors that emphasize the social aspects of designing using "Design Is fundamentally A Social Process" [38][39] and Design Is An Argumentative Process [40] respectively. Schön employs the metaphor of Design Is A Reflective Conversation [17], or Design Is Problem-Setting [24] which emphasizes the two-way and developing nature of designing. Still others have suggested alternative metaphors such as The Design Process Is A Story to emphasize a use of narrative in interaction design [41].

We suggest that the Design Is Search and Design Is Decomposition perspectives are most suited to designing where problems are 'well-defined', where a solution space can be 'mapped out.' In contrast, the people-centered design movement in product development operates in a situation that is more difficult to map out. Here designers are encouraged to "understand the situation from the user's perspective." Companies such as IDEO expand their knowledge by repeated prototyping to learn about the situation. The Design Is Problem-Solving metaphor is less appropriate when the problem itself cannot be agreed on or is understood differently by users and designers. When Problems Are seen as Puzzles it reinforces a 'once-and-for-all' nature of a solution which is rarely the case in product development (though this can be the case in engineering design) – each solution in turn creates new problems or possibilities. The multidisciplinary nature of product development teams also reinforces the appropriateness of Bucciarelli and Rittel's perspectives.

The Design Is Search metaphor also presupposes that a solution exists out there if you look hard enough. The more people-centered approaches encourage a more iterative approach as the team *constructs* a shared understanding of the problem and potential appropriate solutions. Indeed, some resistance to the classic Design Is Search perspective is illustrated by the now cliché imperative to 'Think outside the box,' where 'the box' is the standard design space others are searching in.

The design metaphors presented by different authors may also be an expression of different periods and design cultures. New perspectives on design are accompanied by a shift in the metaphors in use for design and some of it's fundamental concepts. The shifts from Design Is Search, which emphasizes the functional aspects of a design situation, to the later perspectives of, for example, Design Is A Social Process, which emphasizes the social nature of the designers themselves, is a good example of such a shift.

Different views of design lead to different core metaphors

Different views of design are accompanied by different emphases of metaphors for the core design concepts. While most authors referred to the core concepts such as ideas and problems in multiple ways, largely as many chapters included a survey of different techniques and approaches to concept generation, each consistently referred to the concepts using some metaphors in preference to others. Interestingly the choice of overall design metaphor appears to strongly affect the subsequent choice of metaphors for the core design concepts of problems, ideas and solutions.

For example, a view of Design Is Search is accompanied by greater use of the metaphors Problems, Ideas and Solutions Are Locations. Alternatively, Problems may be Obstacles or Gaps blocking the path between Need and Solution. Also common in the Design Is Search metaphor is that Problems, Ideas and Solutions Are Objects, as objects occupy a location in a space. The metaphors of Problems, Ideas and Solutions Are Objects is more often seen, however, together with a view of Design Is Decomposition. As objects they are easily decomposable and reconstructed. When Design is viewed as

Exploration, Design Methods Are Maps, Guides, Signposts or a Compass. When Design is viewed as Problem Solving, Problems Are more often seen as Puzzles to be solved; rather than searching in the wrong area, it becomes possible to solve the wrong problem.

In this way, our understanding of design is hierarchical and is reflected in the metaphors we use. At the highest level is our view of design itself. Beneath that, our understanding of design's core concepts changes according to the design metaphor currently in use.

This use of metaphor in our understanding of design contrasts with the use of analogy in design which is used primarily as a design tool, in particular during the concept generation phase [42] by making a connection with an existing product or system.

Some metaphors are largely universal

While we observed that many metaphors are largely specific to an author's philosophical, and even personal, approach to design, such as Design Methods Are Maps, other metaphors appear largely universal and were shared by all authors. These include metaphors such as Ideas Are Food, and Ideas Are Plants as in "I need time to digest your ideas," and "I have the seeds of an idea." These metaphors appear largely familiar as they are reflected in common language. Compared to everyday language, however, design discourse has a more diverse range of metaphors for the same concepts, for example, Problems Are Gaps In A Solution Space. We believe this reflects a more nuanced understanding of these concepts deriving from greater use and discussion.

Specific implications

Lastly we examine some of the implications from specific metaphors identified in the study, as well as limitations of the study.

Ideas Are Tangible, Physical Objects

Many metaphors for ideas refer to Ideas As Tangible, Physical Objects. Physical Objects have certain common affordances such as occupying a location, being possessions, originating somewhere, being modifiable and so on. This metaphor is reinforced by our experience of 'capturing' an idea on a Post-It or with a sketch. An interesting conflict, however, is that the nature of ideas is often very different from the nature of physical objects. We believe this mismatch is the cause of many difficulties and conflicts during the design process.

To see that ideas don't always behave as physical objects we need only consider that when you give an idea to someone else you still 'have' it. Ideas do not add up in the same way as objects. Michael Reddy's Conduit Metaphor discusses how words, in effect, act as containers for ideas. Following this metaphor when we capture an idea in writing, on a Post-It say, the idea is contained within those words; it is captured. Yet design team members can, and regularly do, interpret those words in different ways than intended. After *handing* someone an idea it can be dangerous to assume that they then also have the same idea. We construct an idea from the words, it is not transferred in the words. It can therefore be very misleading to treat Ideas As Tangible, Physical Objects, as in many ways they do not behave like them at all. The notion that Ideas Are Tangible, Physical Objects also underlies the system of Intellectual Property. If Ideas Are Objects then they can be possessed, protected, and even stolen.

Ideas Are Children

Ideas are also conceptualized As Living Entities, in some cases Children, as when we talk about an idea being born, growing, being nurtured or being your brainchild. Inventors are often known to refer to their invention as their 'baby.' No wonder the threat of an idea being stolen is a serious one, as when a team member attacks your idea. This common metaphor may also explain the tendency for designers to fixate on a single or small number of initial designs [43]. The Ideas are Children metaphor could also be viewed as a specialized form of Ideas are Living Entities, which can evolve, grow, be nurtured, be killed, be dangerous, etc.

Finding solutions

Within the Design Is Search paradigm, Solutions are typically seen as both Objects and Locations. It is these metaphors that enable us to find, discover and search for solutions. These metaphors hide the assumptions that solutions already exist and simply need to be found; with enough searching in the right place you will find them. An alternative view is "The good idea is not discovered or undiscovered; it comes, it happens," [32] p.75. Yet, it is rarely the case that solutions are found ready-made. These metaphors lead us away from the more collaborative notions that Solutions can be constructed and evolve as you build an understanding of the design situation.

Incoherent metaphors

Our analysis also highlights the remarkable range of conceptualizations we hold for such a universal design concept as a Problem. When Problems can be seen as Puzzles, Formulas, Gaps, Barriers, Objects, and Locations not surprising that there is continued debate and disagreement as to the nature of design problems. Our analysis shows that our views of design problems stem not only from the circumstances of the design situation but also the overall philosophy for design of the designer. When these philosophies diverge, debate can be difficult at a more specific level as we find ourselves literally talking about different things.

Creative design

We observed that references to creative design typically took several forms. For example, Ideas appear *involuntarily* or *spontaneously*, they are *triggered* or they *emerge uncalled for*. Our metaphorical understanding of this process sees the Ideas themselves as out of our control and moving of their own

volition. Creative inspiration employs the metaphor Knowing Is Seeing with Ideas Are Light Sources [2]. In this way, Ideas are the illumination, the creative spark or the flash that light up a portion of the design space or illuminate a solution directly. Finally, the metaphor Problems Are Gaps or Obstacles leads understandably to the common notion of the 'creative leap." In the creative leap we move locations, and therefore states, via the common metaphor States Are Locations [6].

The 'out of our control' nature of metaphors for creative ideas, together with the spontaneity implied takes the emphasis off the hard work that is needed for creative design. Consider Edison's mantra "Genius is 1% inspiration and 99% perspiration," or the advice of Bernie Roth at Stanford University that "Hard work is the best creativity method I know" [44]. The metaphors also highlight the individual contribution of creative activity perpetuating the myth of the lone inventor and down playing the role of constructive collaboration in teams.

Summary and future work

Metaphors are frequently used in the design process. This research qualitatively describes their use in a representative sample of textbooks in engineering design. This research lays the foundation for future work in identifying how metaphors can enrich and expand the design process and where they may inhibit or restrict creative design.

Following an analysis of the language used in the concept generation chapters of nine widely used engineering design textbooks we presented both the metaphors in use for the core design concepts of Ideas, Problems and Solutions, as well as the overall metaphor for design itself. We found that different overall perspectives on design leads to different metaphors for the core design concepts. For example, a view of Design Is Search is likely to employ the metaphor Problems Are Locations, whereas a view of Design Is Decomposition is likely to employ the metaphor Problems Are Objects.

We are following several avenues for further research. We intend to develop this study by comparing the metaphors in use by design authors and the impact on the more concrete design methods they recommend. By extending the analysis beyond the conceptual design chapters we also hope to evaluate if patterns are present throughout the entire approach of an author. Also, while this study draws on the metaphors in use in design education as 'transmitted' through design textbooks, we intend to verify whether the same metaphors are in use by design students after studying product development. To this end we are currently repeating the analysis using verbal protocol analysis of design discourse from design students. As our goal is to better understand how metaphors affect creative design we further hope to test the effect of different metaphor models for design through experiment.

ACKNOWLEGDEMENTS

We thank Alan Shih for his assistance in data gathering and analysis for this study. This research was partially funded by NSF grant DUE-0428935

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