Chapter 3
A Structure for Design Theory

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3.1 Introduction: The Science-Practice Dichotomy

The field of engineering design research aims to study the activity of engineering design in order to improve it further. While engineering design practitioners could themselves work toward improving their practice through experience, the field of design research adds a component of systematic inquiry toward the development of robust, reliable tools and methods along with their underlying theories and models. This design research inquiry has been historically pulled in two opposing directions—toward scientific theories on one hand, and a greater relevance for professional practice on the other. These two directions are opposing because development of scientific theories drives research toward abstract conceptualization that has general validity while relevance to professional practice requires inquiry to be rooted in the pragmatics of particular situations.

Design researchers in the past have called for design research inquiry to be scientific. Over the decades, the perspective of what is scientific has included both the design activity itself and the inquiry on design. Researchers initially took the view that design activity itself could be scientific. Simon [26] in his influential work the "Sciences of the Artificial" proposed what he called "science of design." He considered the design process as a rational problem solving process that was amenable to scientific formalism and eventual embodiment into a computer program. This was concurrent with the development of first generation design methods that employed a rational approach to designing [2]. However in the 1970s and early 1980s, the real-world applicability of these methods became suspect with the acknowledgment of design problems as 'wicked' or ill structured [5, 24]. This

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led to the development of science of design, where researchers considered the inquiry into design to be scientific [7]. This is evident in calls by researchers to move the field toward development of scientific theories [8]. A number of design theories employing formal logic such as the General Design Theory [37], Axiomatic Theory [29], and C-K Theory [14] were developed. These theories have led to prescriptive methods for professional practice, but they have not yet been able to become relevant in the context of the artistry of professional practice that [25] mentioned.

The pull toward greater relevance for professional practice began when first generation design methods were found to be inadequate in real world situations. Recognizing that professional situations are often messy, [25] called for an epistemology of design practice that overcame the limitations of the model of technical rationality derived from the sciences and accounted for the skillful artistry of the practitioner. He proposed a framework of reflection-in-action that describes how designers create theories-in-action, perform on-the-spot experiments to test those theories and reframe to create new theories as "the situation talks back to them." Around the same time, researchers started conducting ethnographic studies of design practice to better understand its messy realities [4, 13]. The 1990s and 2000s witnessed a rise in descriptive studies of design practice using methods such as ethnography, video interaction analysis and conversation analysis derived from the social sciences [18, 20, 33–35]. While these studies advanced the analysis of design practice, the flow of knowledge remained in one direction—from practice to research. Descriptive studies rarely influenced design practice. Blessing et. al [3] pointed out that reasoning based on experience and logical argumentation were more common than descriptive studies as starting points for development of methods and tools.

Thus, the science-practice dichotomy has been playing out in the field of design research with the increasing appearance of scientific theories that miss the realities of professional practice, and of descriptive studies that lack relevance for practitioners. It needs to be noted that theories such as Hatchuel and Weil's C-K theory and Suh's Axiomatic theory have had an influence on practice (see Agogue et al. in this book). But this influence often takes the form of rule-based methods that constrain the moment-to-moment artistry of professional practice. If design research were concerned only with study of design activity, it would have been acceptable to develop scientific theories, or conduct descriptive studies. However, since the improvement of practice is the eventual objective of design research, the theories that are developed need to be rooted in the pragmatics of professional practice that are dealt with by descriptive studies. In this chapter, we propose a structure for design theory that retains scientific formalism while enabling design practitioners to use the theory in their ongoing "conversation" with the evolving design situation as described by [25].

3.2 A Structure for Design Theory

3.2.1 Why Focus on the Structure of Theory

Following Dörner [9], we consider a theory to be a formulation that explains a phenomenon, and a model as an abstraction that simulates a phenomenon. Simply put, models do things while theories explain things. Given this purpose, what could a theory look like? What is its structure?

These questions are relevant in design research, because theory is a term that is often misunderstood. For example, is Pahl and Beitz's [22] prescription of design method, a theory or a model? Given Dörner's definition, it fits the description of a model in that it prescribes the design process but does not give an explanation of why the prescription is the way it is. However, researchers [14] include it in their review of design theories.

The discourse on theory in the field of organizational behavior provides a clue toward why this misunderstanding may exist. Sutton and Staw [32] in their paper 'What theory is not' pointed out the following five ways in which authors tended to confuse the term theory.

1. References as theory
2. Data as theory
3. Variables or constructs as theory
4. Diagrams as theory
5. Hypotheses or predictions as theory.

They acknowledged that theory needs to answer the question why and none of the above five elements answer that question. However, Weick [36] in response to this article pointed out that we need to consider not just theory, but the process of theorizing. Perhaps references, data, constructs, diagrams, and hypotheses could be part of the theorizing process—developments on the way to a complete theory. Similarly, the models, frameworks, and principles that abound in design research could be considered as elements on the way to a theory rather than theory themselves. So what is the end form of the process of theorizing in design?

In order to answer this question, we first examine the structure of scientific theory and the perception–action perspective from ethnographic research.

3.2.2 Structure of Scientific Theory

Our examination of scientific theory derives from the field of philosophy of science in which the structure of scientific theory has been a topic of continuing discourse. The structure of scientific theory has been described in terms of two different views, viz.

1. The received view of scientific theory
2. The semantic view of scientific theory.

The received view of scientific theory

This perspective defines a three-part structure for scientific theory. The first part deals with logical formalism, the second part describes observable constructs and the third part describes theoretical constructs. The three parts are connected by rules of correspondence that hold the mathematical, observable, and theoretical constructs together. See Frederick Suppe's "The structure of scientific theory" [30] for a detailed account of the received view as well as its historical development. The received view of scientific theory has been heavily critiqued and rejected by most philosophers of science [31]. The main reasons for its rejection were the difficulty in conceptually separating physical constructs into observable and theoretical dimensions, the difficulty in creating correspondence rules between formal logic descriptions and observable constructs, and the rigid structure that admitted only logical calculus of the first order to accept as formal descriptions of theory (ibid). The received view of scientific theory gave rise to the semantic view that adopted a less rigid approach to theory description.

The semantic view of scientific theory

Craver [6] specifies the semantic view or the model view of theories as the idea that theories are abstract extra-linguistic structures quite removed from the phenomena in their domains. In this view, theories are not associated with any particular representation. Researchers have a much greater freedom than in the received view to describe their theory in terms of a series of models that explain a set of phenomenon through abstraction constructs that constitute the theory.

Given these two views, we believe that the received view could be adapted to create a structure for design theory. We choose the received view over the semantic view as a point of departure even though the received view has been heavily criticized because of the following reasons.

1. The multiple dimensional structure of the received view is well suited for accommodating both the theoretical constructs and the relationships between them, and the perception–action component that makes the theory relevant to professional practice. The perception–action component is described in greater detail in the following sections.
2. The factors for which the received view was criticized can be overcome in a formulation that avoids rigid definition of logical formulation, and ambiguous separation between theoretical constructs and observable constructs.
3. The existing theories in design research such as C-K Theory, Axiomatic Theory etc., are more suited to formulation in the received view than in the semantic view.
4. The theories of classical physics that underlie engineering analyses as expressed in the received view are more intuitive to engineering design researchers and practitioners.

3.2.3 The Perception–Action Perspective

From an examination of the structure of scientific theory, we move on to examine the elements of professional practice. Our examination is based on Goodwin's description of professional vision [11, 12] and Ingold's [16] study of skill in the development of technology.

Goodwin [11] takes the example of field archeology to describe how perception and understanding of events is socially organized by professional groups into what he calls professional vision. Professional practice is considered to be "a temporally unfolding process that encompasses both human interaction and situated tool use." It is this tool use and the associated human interaction that helps professionals develop a perceptual field that highlights information relevant to a particular professional practice. In the field archeology example, Goodwin points to the Munsell color chart that is a tool used by professional archeologists to detect the color of dirt during digs. The chart is a tool that encodes the theory and practice of previous workers and provides a perceptual aid to highlight information that might otherwise be hidden. The artistry of professionals then lies in the ability to use sophisticated perceptual fields, decode the information that is highlighted and respond to the situation unfolding in front of them. Professionals develop their own action repertoire corresponding to the perceptual fields they encounter, their previous experience, and the theories that underlie professional education.

Ingold [16] too spoke about the role of perception and action in the development of technical skill. He regarded technical processes such as engineering design not as products of intelligence, but as practices of skill, where skill was defined as the coordination of perception and action. Ingold argued that if we want to understand a skill we need to "shift our analytic focus from problem-solving, conceived as a purely cognitive operation distinct from the practical implementation of the solutions reached, to the dynamics of practitioner's engagement, in perception and action, with their environments."

Given the recognition of perception and action in the development of skill relevant to domains such as engineering design, we believe that design theory needs to include a perception–action component that would enable it to be directly relevant to the artistry of professional practice. Combining this perspective with the examination of the structure of scientific theory, we propose the following structure for design theory.

3.2.4 A Structure for Design Theory

We propose a structure with two dimensions.

1. The event-relationship dimension
   The event-relationship dimension mentions the event or sequence of events that the theory attempts to explain by providing the definition of theoretical

constructs—i.e., variables and operators, and the relationships between them. These relationships can be expressed either in natural language such as English or in formal logic.

2. The perception–action dimension
The perception–action dimension describes the perceptual field and the action repertoire associated with the theoretical constructs in situations of professional practice. Perceptual field and action repertoire were defined in our earlier work [17] as follows.
We define a perceptual field as sensing organized around a purposeful activity. With the notion of a perceptual field we want to refer to what one notices when one is engaged in the activity of designing. This noticing can refer to things in the environment or to internal states and feelings. A perceptual field can, for example, be set up through disciplinary training, or through certain media that make specific characteristics salient. Re-framing in terms of a perceptual field means shifting from one perceptual field to another perceptual field. This idea of perceptual field is captured in the idea of a "model" or "point-of-view" of the world.
Analogous to a perceptual field defined with respect to sensing, we define an action repertoire as organized movement within a purposeful activity. With an action repertoire we want to refer to the choices from a corpus of behaviors a designer has when engaged in the practice of designing. An action repertoire can be seen as the corpus of behaviors a designer has at his or her disposal when engaged in a conversation with the situation.

The two dimensions—event-relationship and perception–action characterize the phenomenon the theory explains but in different ways. The event-relationship dimension gives a logical formulation of the involved parameters and their inter-relationship, while the perception–action dimension provides the elements necessary for practitioners to actually perceive and act on the parameters involved. It needs to be noted that merely formulating a design theory in this structure does not make it scientific. Following Popper's [23] falsification principle for a theory to be scientific, researchers need to infer hypotheses that test the theory by being amenable to falsification. The two-dimensional structure for design theory provides an opportunity for the necessary scientific testing while being rooted in the perception–action of professional practice. The following section gives an illustration of the proposed structure for design theory as applied to C-K theory.

3.3 Example: C-K Theory Formulated in the Two-Dimensional Structure

The following formulation is derived from the exposition of C-K theory as given in Hatchuel and Weil [14, 15]. The formulation is presented in normal font while our comments are given in italics.

3.3.1 The Event-Relationship Dimension

Event explained: The generation and development of concepts in design practice.

C-K theory as postulated by Hatchuel and Weil [14] *claims to be a unified design theory. However, using a two-dimensional design structure with a perception–action component necessitates a more specific formulation. Hence, we formulate C-K theory not as a unified theory of the entire design activity, but a theory of generation and development of concepts in design practice. This implication of the two-dimensional structure is discussed further in* Sect. 3.4.

Construct definitions:

- Knowledge Space (K)—The space of propositions that have a logical status for a designer D.
- Logical status—An attribute that defines the degree of confidence that D assigns to a proposition. Logical status in standard logic can be true or false. K space propositions are assigned a logical value true/false by the designer D.
- Concept Space (C)—The space of propositions that have no logical status in K.
- Design—The process by which concepts generate other concepts and are ultimately transformed into K space, i.e., propositions that have a logical true/false status.

Further characterizations of C and K spaces as mentioned in Hatchuel and Weil [14] *are not included here, as we do not intend to give a detailed account of C-K theory but use it to illustrate theory structure.*

Relationships:

C and K are mutually exclusive sets that taken together describe the entire universe of propositions expressed when designing. Design progresses because C and K exist. If either ceases to exist, design would itself cease.

Propositions expressed during designing undergo transformations from C to K, C to C, K to K, and K to C.

External operators—Operators transforming propositions between C and K.

- C –> K: Propositions in C are transformed into K when they acquire a logical status of true/false. Hatchuel and Weil describe this operator as corresponding to validation tools or methods such as consulting an expert, doing a test, conducting an experiment, building a physical mock-up or prototype and testing it.
- K –> C: Propositions in K can be extended into C space when they pick up attributes that do not have logical status through the process of concept generation. For example a car has logical status in K space, but a car powered by cold fusion is a proposition in the C space because it has picked up the attribute of cold fusion that itself does not have a true/false status.

Internal operators—Operators transform propositions within C and within K.

- C –> C: Propositions in C can be partitioned further or combined together to form new propositions.
- K –> K: Propositions in K can lead to new propositions in K through knowledge derivation processes such as induction and deduction.

3.3.2 Perception–Action Dimension

This dimension describes the pragmatic situation, i.e., sets of perceptual field and action repertoire that correspond to the theoretical constructs (relevant events and relationships) explained above. For a given set of theoretical constructs there could exist multiple sets of situation—perceptual field—action repertoires depending on the interactions that typically occur in professional practice. We next describe the perceptual field and action repertoire related to the situation of group concept generation.

Situation: A team of engineering designers generating concepts through conversation. The team is situated in a room equipped with whiteboard, markers, table and chairs, and paper for sketching.

Perceptual field of individual designers: Both C and K are articulated by individuals in the group in the form of verbal and non-verbal elements of the conversation. The perceptual field enables designers to distinguish C from K. In our prior work [27], we have identified the certainty expressed through language as an indication of K space and use of conditional language as an indication of C space. Hence, perceptual field for C consists of the following.

1. Expressions that are explicitly called out as concepts either in verbal form or are written down in an explicit list on whiteboard or paper.
2. Expressions indicated by use of conditional terms—could, might, maybe, if. In some cases "would" might also imply conditionality.
3. Expressions indicated by use of 'should' coupled with a conditional term—"maybe we should" or used as a question—"should we do it that way?"
4. Expressions indicated by generative design questions [10]—e.g., scenario creation or proposal creation questions like—"how about…?", "what if…?", "what about…?"
5. Expressions indicated by use of analogies to indicate possible alternatives…"something like Mr. potato head".

The perceptual field for K consists of the following expressions that indicate certainty on part of the individual making that expression.

1. Personal or team narrative—something that happened in the past to an individual or team.
2. General knowledge—something that is accepted to be true, e.g., principles of how a mouthwash works.
3. Personal opinion—opinion including likes and dislikes that were expressed by an individual.
4. Project requirements—expressions related to project requirements.

5. Process—comments on the ideation session going on at the moment.
6. Future certainty—expression of what should happen in the future, rather than what could possibly happen.

The perceptual field enables C and K to be experienced by individual designers in the given situation. Concepts and Knowledge are no longer just abstract constructs but real entities that can be perceived and responded to.

Action-repertoire: Action-repertoire for C-K theory lists the actions designers can take to progress in generation of concepts and their conversion to knowledge. The following list of actions is derived from our previous work [27] on concept generation in engineering design teams.

1. Introduce C or K expressions—Introducing new C or K expressions in a conversation can occur in response to questions by others in a team or as a result of new concepts generated at an individual level.
2. Support C or K expression—Expressing support to C or K expressions given by team members can take the form of nodding and expressing approval, giving a compliment to a C expression, or articulating a narrative that lends further support to a K expression.
3. Build on C expressions—Building on C expressions occurs when an individual listens to a C expression by a team member and adds new attributes to it or develops an analogous C expression. This is the C –> C operator discussed in the theoretical constructs dimension.
4. Blocking C or K expressions—Blocking C or K expression can occur with an individual expressing doubt, disapproval of a C expression, or an opposing K expression.
5. Negotiate blocks to generate new C or K—When a block is given, it needs to be resolved for the conversation to proceed further. This resolution occurs when teams accept the block and reject the C or K that is creating conflict, or generate new C that overcomes the opposition or disapproval, or bring in new K that dissolves the opposition into accepting the C or K in conflict.
6. Introduce questions to generate C or K—Generative design questions direct the conversation to generate new Cs and deep reasoning questions direct the conversation to generate new Ks [10].
7. Generate commitment to evaluate C into K—Individuals can generate consensus on which concepts to prototype and develop further through planning, question asking or encouraging action, e.g., "Let's meet today evening to make a prototype."

The inclusion of an action-repertoire enables designers to not just perceive C and K but also develop the skill of responding to them in situations of professional practice. The following example shows the unfolding of perception–action in a concept generation conversation with the help of the *Interaction Dynamics Notation. Interaction Dynamics Notation* [27] *is a visual notation that captures the C-K dynamics of group conversation. C expressions are captured in red color, K expressions in black color* (Table 3.1).

Table 3.1 An excerpt of conversation of four engineers engaged in concept generation taken from Sonalkar [27]

Transcript

Engineers A, B, C, and D are engaged in generating concepts for a new dental hygiene product

B: So how about sandpaper, we haven't talked about sandpaper much. Like, I guess that's-

C: I feel like whenever I listen to sandpaper I have this really negative mental image of like grinding (B says "Oh yeah" and starting making a grinding sound) away the enamel of your teeth

D: Yeah

B: So what about-

C: So-

B: But-

D: Think of it more as like a loofah

C: Yeah (laughs)

A: But I mean, that doesn't mean we don't have to use real sandpaper obviously something some kind of like (C says "Yeah I know") an abrasive on a sheet or something

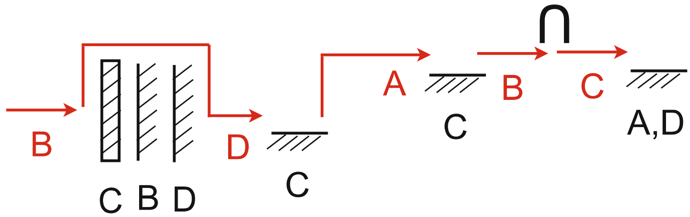
B: Let's improve on floss, like the ribbon that you slide (gesturing flossing)

C: It could be floss, sandpaper floss that's a good thing

A: (says something simultaneous with C) slightly abrasive ribbon, yeah

D: Yeah

Interaction dynamics notation of the above conversation (Red indicates expressions in C)



Perception–Action comments

B introduces a new concept "how about sandpaper" into the conversation. However person C expresses dislike and gives a block (indicated by the barrier in the notation). B and D express support to the block. However, D perceives the block to the concept and tries to negotiate the block by person C by proposing an alternative perspective "think of it as a loofah." This is indicated in the notation above by the symbol that goes over and around the barrier. Person A accepting C's dislike tries to introduce another concept, something that is not sandpaper, "an abrasive on a sheet or something." B introduces the concept of something like a floss, person C perceives the new concept expression and builds on it to suggest a sandpaper floss as indicated by the inverted 'U' symbol. The notation is given here as an illustration of a visual C-K representation that captures moment-to-moment dynamics of the situation. The notation and its development are described in detail in Sonalkar et al. [28]

3.4 Implications of the Structure for Design Theory

Proposing an explicit structure for theory formulation with a perception-action dimension in design research has the following implications.

1. From grand theories to specialized theories—The inclusion of perception–action component, which is rooted in situations of professional practice, precludes the formation of grand unified theories of design. If we were to develop a

unified theory of the entire design process, then the perception–action dimension would include all activities that engineering designers perform and it would be prohibitively complex. Instead of grand unified theories, the proposed two-dimensional structure for design theory encourages researchers to develop theories pertaining to specific situations encountered in professional practice. Thus, we could develop a theory of prototyping, a theory of concept generation, a theory of concept evaluation, a theory of requirements analysis etc. We believe that this would enable design researchers to address the complexities of specific situations to develop logically sound theories grounded in professional practice that are amenable to scientific testing.

2. No more pseudo theories—If we know the destination, we would know when we have reached it. If we don't know what the end goal of theory building is, there is a greater possibility of creating pseudo theories by confusing one of the interim stages with the theory itself. Accepting a common structure for design theory has the implication of precluding the development of pseudo theories. Researchers would now have a benchmark as to what is a theory and what is not. Thus, when they are publishing the artifacts of their theorizing that are not yet theory, they could be more open and inviting to receive constructive feedback that could accelerate the development of a specific design theory that is appropriate to their finding.
3. Collaboration between formal theory researchers and observational studies researchers—Including both a perception–action dimension and an event-relationship dimension in the formulation of a design theory implies that researchers conducting ethnographic studies and researchers who traditionally focused on formal theories need to work together. Just developing theoretical constructs or just describing the perception–action in professional practice is not enough. The interplay between formal theoretical constructs and actual empirical events holds the promise to resolve the science-practice dichotomy and create a more cohesive, focused research community.
4. More resources needed to build theories—With the need for greater collaboration between researchers to build theory comes the need for greater resources. Theory building for the two-dimensional design theory would be more expensive in terms of both money and time requirements than building only a formal design theory. However in long term, with greater collaboration and more focused research efforts in the field, the resources required for the field of design research to progress would perhaps be less than those required if the current situation of division and isolation in the field continues.
5. Practitioners can contribute to theory building—With the inclusion of perception–action dimension in design theories, reflective practitioners can make significant contributions to design research. Theory need no longer be a pejorative term of abstract meaningless thinking for practitioners. It can become an indication of intellectual rigor in one's practice that goes hand-in-hand with increased skill and we hope better design outcomes.
6. Encouragement of adaptive design expertise—Most prescriptive models such as Pahl and Beitz [22] that scaffold design practice mention a procedure that

designers need to follow. They do not encourage or even acknowledge the skillful artistry of professional practice that involves perceiving and responding to the situation at hand. Including a perception–action dimension in design theories could promote the acknowledgment and training of the skill needed for professional practice. Neeley [21] defined adaptive design expertise as the ability to combine active engagement with reflective thinking in order to mindfully adapt to a design situation. The two-dimensional structure of design theory that includes both the reflective and the active part could encourage the development of such adaptive design expertise.

3.5 Critique of the Design Theory Structure

The proposed two-dimensional structure is an outcome of our efforts to resolve a perceived dichotomy between the drive toward formal theories with greater scientific rigor, and our experience of design practice that rarely relies on the tools and methods of design research. In 2010, we had proposed the development of a separate category of theories called the perception–action theories [17]. However, we realized that it does not help resolve the science-practice dichotomy. It helps practice oriented researchers create their own set of theories. But this could propagate further divisions within design research without leading to collaborative cohesive efforts to bring in relevance to design practice. The two-dimensional structure for design theory is a step in that direction. However, it raises several concerns, three of which will be discussed here for illustrative purposes.

3.5.1 Integrity of Perception–Action Dimension

If theory is a formulation that explains, then should perception–action be part of it? The perception–action dimension does not explain, but rather gives reflection of the theoretical constructs in situations relevant to practice. So should it not be considered an application of theory?

We argue that perception–action dimension needs to be an integral part of design theory based on (1) the nature of design activity and (2) the purpose of design theory.

(1) Design theories where human agency is a factor are not the same as natural science theories, e.g., the big bang theory in physics, where there is no human agency. Humans are subject to biological and other physical constraints but are not determined by these forces. The two-part theory is consistent with theories in the field of feedback control—where we include humans in the control loop (see the cybernetics systems perspective described in Maier et al. in this book). The perception–action dimension accounts for the human agency in design and hence is an integral part of design theory.

(2) The purpose of theory is to explain a phenomenon. However, in designing its theories a field of study needs to also consider whom this explanation needs to be given to. We believe that the field of engineering design research needs to develop theories that are accessible by and meaningful to both researchers and practitioners. The perception–action dimension enables this by letting the theory be rooted in situations relevant for professional practice. The perception–action dimension also sharpens the theory because it now proposes perceptual fields that theoretical constructs need to be compatible with. There is much tighter coupling between logical relationships and the situational relationships of constructs that design theory uses to explain phenomenon.

3.5.2 Defining a Boundary for the Perception–Action Dimension

Does the perception–action dimension have a boundary in terms of the kinds of situations that need to be included? Without a defined boundary, this dimension could remain open-ended and researchers could simply keep adding perceptual field and action repertoires to a design theory.

The boundary of the perception–action dimension depends on how the constructs of the theory are operationalized in professional practice. The boundary would be better defined in theories that are context specific, and ill-defined in theories that attempt to explain multiple disparate situations in the design process.

The perception–action dimension is grounded in an interaction perspective of the professional world with the underlying assumption that professional practice is socially and materially constructed. It is the interactions that we have with the people around us and with the tools in our environment that define our practice. The kind of interactions we have can themselves be sufficiently abstracted to prevent an overloading of perceptual fields and action repertoires on a design theory. The development of the Interaction Dynamics Notation [27] that abstracts concept generation conversations into a visual notation gives an indication of the methodology through which this abstraction could be achieved. Thus in the example of C-K theory mentioned in this article, we need not mention perceptual fields and action repertoires for all different concept generation conversation occurring in various parts of the world. Instead one set of perceptual field and action repertoire is sufficient to cover such conversational situations.

3.5.3 The Tension Between Generality and Specificity

As mentioned in the implications section, the proposed structure for design theory is biased against the formulations of grand unified theories of design. However, a theory by convention needs to be sufficiently general enough in its explanatory power to cover a number of unique cases of practice. Does this not create a tension within a theory to be both general enough in its theoretical constructs dimension and specific enough in its perception–action dimension?

We believe it is important to distinguish between bounding the phenomenon that a theory attempts to explain and the generality of that explanation. An example of bounding the phenomenon is that we build a theory of prototyping that is a component of the design process, rather than a theory of the entire design process. However, this does not restrict the generality of the explanation that the theory provides for the prototyping phenomenon. Different prototyping situations could be explained by such theories. The development of the perception–action dimension could encompass such different situations. As mentioned above, the interactions that occur during prototyping could be sufficiently abstracted to develop relevant perceptual fields and action repertoires.

3.6 Summary

In this chapter, we have described a science-practice dichotomy in design research that is manifest in a drive for scientific rigor and formal theories on the one hand and a greater relevance to professional practice on the other. We pointed out the need to not only create prescriptive models for practitioners, but also recognize and enable their artistry in dealing with the messy realities of practice. To enable this, we proposed a two-dimensional structure for design theory that includes an event-relationship dimension and a perception–action dimension. We explained the origin of this structure, its description, its implications, and commented on some of the concerns it could raise for design researchers. We hope that the proposed structure for design theory will start a discussion among design researchers that will eventually lead to better design theories with greater relevance to design practice.

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