

Distributed Cognition as an Approach to Understand Design Thinking in Practice

James Self*

Department of Design, Professor, UNIST(Ulsan National Institute of Science and Technology), Ulsan, Korea

Abstract

Background While design thinking is now established as method for creative problem solving, continued efforts towards theory construction to explain design thinking are ongoing. To contribute to an understanding of design thinking, I position a distributed theory of mind as scaffold to explain design thinking in practice.

Methods I commence with a discussion of design thinking, its foundations and evolution to describe a process applied to enhance creative problem solving. I then discuss how a distributed theory of mind may help explain the designer's construction of design representations, as scaffold for thought towards propositional design solutions.

Results A distributed approach to explain design thinking aligns with more established design theory: wicked design problems, appositional reasoning, and problem framing.

Conclusions Due to design's applied nature, and the constructed emergence of design representations as distributors of thought towards future solution possibilities, a distributed theory of mind (re)positions design practice, skill and expertise as fundamental to design thinking.

Keywords Design Thinking, Distributed Cognition, Design Theory, Design Representation

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2023S1A5A2A01075989).

*Corresponding author: James Self (jaself@unist.ac.kr)

Citation: Self, J. (2025). Distributed Cognition as an Approach to Understand Design Thinking in Practice. *Archives of Design Research*, 38(2), 33-43.

<http://dx.doi.org/10.15187/adr.2025.05.38.2.33>

Received : Sep. 02. 2024 ; **Reviewed** : Mar. 16. 2025 ; **Accepted** : Mar. 16. 2025

pISSN 1226-8046 **eISSN** 2288-2987

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1. Introduction

The term *design thinking* is often used to describe a process comprising a series of activities, the aim of which is to enhance creative problem-solving. Gibbons (2016) defines design thinking as a process aimed at facilitating creative problem-solving and comprising six phases: *Empathize, Define, Ideate, Prototype, Test, and Implement*. Explained in this way, design thinking is a process used to stimulate and enhance creative problem-solving ability. The emergence of design thinking as process can be traced back to the work of Stanford University's Hasso Plattner Institute of Design (known as Stanford d.School). Tim Brown's (2009) influential book *Change by Design: How Design thinking Transforms Organizations and Inspires Innovation*, extended the reach of design thinking to audiences beyond the design academy. The popular emergence of design thinking, and its appeal in introducing a designerly process, points to the applied nature of design thinking. However, works that position design thinking as a type of process (Gibbons 2016, Brown 2009) are often less interested in explaining the interaction between design as applied practice, and design thinking as type of human cognition.

While design thinking is now established as approach to creative problem-solving, its precise definition remains contested. Prior to the emergence of design thinking as process, previous works pursued an understanding of design thinking as a type of human cognition. More recently, in a special issue of the journal *Design Studies*, Nigel Cross (2023) appears to lament a semantic shift of the term design thinking as type of cognition (what Cross terms *design thinking 1*), to design thinking as process (explained as *design thinking 2*). This reaction may be due to Cross' early advocacy for design thinking as a particular type of human cognition. To this end, Cross and his colleagues were early contributors to an understanding of design cognition, including the founding of the journal *Design Studies* in 1974 as peer-reviewed publication dedicated to understanding design as a human activity. The *Design Thinking Research Symposia* (DTRS) continues as venue for discussion of design thinking, and its various aspects, practices, ways of doing and knowing (DTRS14 *The Role of Design in Shaping Sustainable Futures*, 2023). For a comprehensive review of design thinking's evolution from type of design cognition, to design thinking as process, I direct the reader to Cross' (ibid) contribution.

The aim of the current position paper is to contribute to ongoing discussion of what design thinking is, wherein I focus upon design thinking as particular type of human cognition. To achieve this, I position a distributed theory of mind, adopted from the work of the social anthropologist Edwin Hutchins (Hutchins, 1996; Hutchins, 2001), as lens through which to re-examine design thinking and its relationship to design practice. Through a discussion scaffolded by a distributed theory of mind, I focus on the role and use of design representations as evidence of distributed design thinking. I conclude with a discussion of distributed cognition's potential as theory to help support the study of design thinking and its relation to design practice.

A distributed theory of mind explains human cognition as including the external, material environment within which thinking locates (Hutchins *ibid*). In contrast to a theory of mind that suggests thinking is skull-bound, distributed cognition explains thinking as extended beyond the mind to include both other people and the artifacts within our material environment. How we think, moment by moment, emerges from interaction with our external, material world. In terms design practice, thinking thus explained is scaffolded by the tools, methods and external processes that the designer engages to explore, develop, and finally implement a design solution.

In my use of a distributed theory of mind as possible means to help explain design thinking I focus upon a situated act of designing, as undertaken by the individual. This is not to say design is a solitary activity. Due to its applied nature, designing requires input from various stakeholders working together in complex networks of interactions, activities, and related processes (Ardito et al., 2012). While understanding how stakeholders interact to achieve design is of course important, I focus upon a situated, discrete activity whereby the designer explores ideas towards possible solutions and their development. I introduce design thinking as distributed beyond the mind to include the designer's efforts to propose, explore and test solution possibilities, wherein solutions are framed as possible futures.

2. Design Cognition

The term cognition is defined by Dhakal and Bobrin (2023) as the mental action or process of acquiring knowledge, with acquisition derived from information gathered through the senses. The information we gain from the world around us interacts with our experiences held in memory; that which we bring to foreground the information derived from our senses. Bottom up (senses) and top down (existing memories, attitudes, histories) together inform human cognition.

Adopting a distributed theory of mind to understand design thinking, the designer's expression of solution ideas plays into both top-down and bottom-up knowledge acquisition as thinking is distributed between designer and design representation. Here I use the term design representation to describe the expressions of design intent used by the designer during design process. For example, the ubiquitous design sketch, a design prototype used in product design as propositional articulation of design intent (Pei and Self, 2024). Explained through a distributed lens, design thinking emerges from engagement with expressions of design intent, as the designer interprets a propositional representation filtered through the experiences, skills, and memories she carries with her to a situated practice of design.

Applying a distributed theory of mind, rather than leading from sense data to cognition, distributed design cognition extends to, emerges from and is embedded within design representations as expressions of design intent. Situated in this way, design thinking is explained as a type of distributed cognition associated to the activity of designing. In design thinking, the external scaffold of design representation is constructed by the designer.

Perhaps more uniquely within creative design practices, the aim of construction is to provide an articulation of a future, solution opportunity. Thus design representations, as cognitive artifacts, differ from the concept of a cognitive artifact explained by classical distributed cognition theory (Nemeth et al., 2003). An important aspect of design representations are both their emergent quality, as constructed by the designer in practice, and their articulation of intentionality towards possible future solution opportunities. If an operational definition of designing includes design as representation of ideas - i.e., the construction and use of design representations as distributor for thought - an understanding of design thinking may emerge through investigation of design representation's use in design practice, and as scaffold for design intentionality.

3. Design Representation

From the exploration of solution possibilities to the specification of design intent, design representations are used throughout a process of design. The differing characteristics of design representations, in their approximation of design intent, reflect the changing objectives of design process (Self & Pei, 2014).

Ambiguous, low fidelity approximations of design ideas during design ideation, provide opportunity for (re)interpretation of a design solution. This interpretation acts as support for conceptual design, and the exploration of solution possibilities. Ambiguity's ability to widen an exploration of the solution space appears to be important to conceptual design (Goel & Pirolli, 1992). Applying a distributed approach to explain design thinking, the role and importance of ambiguity in expression of intent may become clearer.

It is often the case that as design progresses, ambiguity retreats as representations evolve to approximate design intent at increasing fidelity and specificity. As thinking is distributed between representation and designer, evolution in the expression of design intent may reflect a shift from an explorative, interpretive mode of thought to the analytical thinking required in the detailed refinement and further progression of design ideas. Thinking towards solution ideas moves from a required ambiguity to provide opportunity for interpretation and exploration during concept ideation, to a more prescriptive and detailed account of a design solution across its various aspects of form, functionality, and interaction. While a simple, linear relationship between ambiguity of expression and design evolution is attractive, in practice design requires a mix of different thinking styles as solution ideas are progressed, changed, revised, and iteratively developed. In adopting a distributed approach to contribute to an understanding of design thinking, evidence for this iteration may be found through examination of the types of representation employed at a given point in process (Conole, 2012; Pei et al., 2011).

In framing thinking as distributed across thought and representation, the design tool used; how it is employed in the construction of design representations, influences cognition. Considering the constructed nature of design representation, distributed design thinking

thus departs from distributed cognition theory (Nemeth et al., 2003; Zhang & Norman, 1994). I use the term construction to describe the ways in which a designer creates the design representation. In a situated activity of design, the designer both constructs and reflects upon the design representation as potential solution candidates emerge. Schön (1989) describes the construction of design representation as a working within an alternative, representational world, whereby ideas are explored, tested, and developed. Adopting a distributed approach may help explain the importance of Schön's (ibid) representational world for the practice of design. However, Schön's reflective-practice paradigm (Schön, 1983) lacks precision in explaining the relation between representation and thought. A distributed theory of mind may help identify and explain the various mechanisms of thought and their interactions in design practice.

For example, designers use a variety of design tools during a process of design to construct representations as approximations of design intent. From paper and pencil in the construction of conceptual sketches, exploring solution possibilities during ideation (Eissen & Steur, 2011, 2014), to high fidelity, pre-production prototyping tools such as 3D printing, employed to construct physical representations of intent to validate a design proposal more comprehensively (Lauff et al., 2020). CAD (Computer Aided Design), 3D Printing, and digital illustration tools are increasingly employed in practice to construct design representations. More recently generative AI has started to impact design process, whereby the AI may have increasing responsibility for the construction of design representation.

Perhaps the most comprehensive taxonomy of design representation is offered by Pei et al. (2009). Four main categories include: *design sketches*, *design drawings*, *models*, and *prototypes*, with various sub-classifications within each of the four taxa. While the categorization of design representations in this way is subject to some interpretation, the extent of the Pei et al (ibid) taxonomy indicates a wide variety of design representations, and tools of construction available to the contemporary designer.

Applying a distributed approach we may be better able to identify and measure the influence of the tool used in the construction of a design representation. This is because the role of the tool is explained by its influence upon the construction of the design representation, and so has forward impact upon distributed design thinking. Explained in this way, different tools will provide both benefits and limitations for design thinking. For example, the ways in which hand sketching and solid modeling software diverge in their influence upon the construction of design representation (Self, 2019), has implication for design thinking as cognition is distributed across designer and representation. Adopting a distributed lens opens up questions around the tool's influence on design thinking in practice; as a distribution between thoughts and representations.

How paper and pencil or CAD tools are used by the designer in the construction of a design representation, also depends upon the skills, experience, and expertise the designer brings to tool use. Adopted a distributed theory of mind to help explain and predict the impact of tool use, would help design educators be more explicit about the implications of tool use for students' process and outcome. Design researchers may examine different design tools, and

the representations they construct, as locations of distributed thinking embedded within and emergent from representational approximations of design intent.

In discussing the role of the design tool in construction of design representations, my aim is to provide an example of a distributed theory of mind's explanatory potential. Applying a distributed approach to understand design thinking has potential to open up various avenues for further investigation. The role of the designer, in the construction and expression of design intent. Interactions between construction, representational expression, and design process. How distributed thinking may depend upon knowledge of process, individual expertise, or interactions between construction, representation, distribution, and communication.

4. Distributed Design Thinking

Design scholars have, over the last 50 years, made significant progress towards building general theory in design thinking. In this final section I will discuss a distributed approach to understand design thinking as it may align with two contributes: the notion of a wicked design problem, and oppositional reasoning between design problems and their solution. In doing I aim to provide illustrative examples of a distributed theory of mind's relation to and alignment with more established design theory.

A problem is a situation, person, or thing that needs attention to be dealt with or solved. Defined in this way, a problem is an objective challenge. It is something external to us. Something that we can point to - metaphorically and/or literally speaking - that demands our attention; that needs to be addressed and resolved. This common definition describes problems as negative, undesirable, or unwanted. We solve problems every day. My son had the problem of not knowing the time of his saxophone lesson. The school forgot to publish lesson times for this semester. The problem is now solved. We have the problem of ants coming in through a small gap between the back door of our house and the door frame. A standard solution would be to put down some ant poison. After reviewing options, I decided to take a different approach of pushing some putty into the opening. Unfortunately the resourceful ants have found a gap at the top of the filler. The problem remains unsolved.

The problems I describe above have a known solution state – i.e. stop the ants. There is also more than one way to go about solving these problems. For example, I could email the saxophone teacher, call the school office, or visit the music department on my next school run. But the end goal, the solution, is known at the start of actions towards problem resolution. While this defines a problem as an objective reality waiting to be solved, problems may also have a subjective quality. Problems need our attention. In this orientation, the extent to which a problem is seen as such, depends on the problem-solver. What is a big problem for me, may be insignificant to you. This feature of a problem - the subjective quality of the problem as seen to be by the problem solver – appears important to a definition of a design problem.

While subjectivity in deciding the nature of the problem; what constitutes a problem worthy of my attention, may be important for some types of problem, science often explains problems as they exist outside our subjective experience. Empiricism, as a foundation for a philosophy of science (Markie & Folescu, 2023) emphasizes the scientific method in the generation of knowledge about the world, pointing to problems both existing as an objective reality and providing opportunity for knowledge gains from their solution. Understanding problems about the world is achieved through testing of assumptions within an objective reality. In this endeavor, empirical scientific methods strive to identify an objective truth about the world that is described as existing outside of ourselves. The empirical, scientific tradition asserts that an objective truth exists, waiting to be discovered.

The empiricist tradition is often contrasted with rationalism (ibid). Rationalism prioritizes subjective reasoning as means to acquire knowledge. We experience the world through our senses, applying reasoning to understand our experience. Rationalism speaks to the problem-solver in her interpretation of what the problem is. Science takes as its starting point the axiom that knowledge of the world is objectively accessible, measurable, and discoverable. In contrast, design problems deal with future solution possibilities that do not exist prior to a design process (Dorst, 2006). In the sciences, methods are applied to a specific area of interest, drawing out knowledge and understanding of the now, wherein the now is an objective reality. However, design is interested in the creation of preferred futures, the problem itself, and the kinds of knowledge required to solve it, must first be defined.

This definition of the design problem is important if the design outcome aims to go beyond existing solutions to propose something new or innovative. A design problem is thus identified through the designer's interpretation of what constitutes the problem. Because of this interpretation, the designer may be better placed to offer more unique, alternative solution possibilities. In this sense design problems and their solutions are dependent upon one another. Cross and Dorst (2001) describe this dependency as a co-evolution of design problems and their solutions.

Starting with a land-mark paper in town planning, Rittel and Webber (1973) identify the wicked design problem. The concept of the wicked problem has been taken-up enthusiastically by the design research community. It is now well established as means to define the type of problem associated with design thinking. Cross (2007) suggests designers seeing problems as wicked means they are then able to respond with more creative solutions. It may be that designers acquire a certain disposition to widening the scope of given problems. The designer may be more sensitive to seeing problems as wicked, complex, and ill-defined. And in doing, is better able to identify more creative solutions. For Cross (op cit.), designerly ways of knowing are anchored in an ability to explore the design problem space. Both because the problem may be complex, and because of the designer's disposition to interpret the problem as complex. To look at problems through a different lens. To examine assumptions, break them, and propose new ideas. Dorst (2015) extends the concept of problem framing as means to understand how designers' approach and define design problems. In re-framing the original problem, designers can explore alternative, more creative solution possibilities.

In both ill-defined problems and problem framing, the designer's interpretation of what constitutes the important aspects of the problem to consider appear important. Design leans into rationality insofar as knowing is based upon the designer's interpretation of what constitutes the problem. Because interpretation is important for problem framing, the designer's skills, expertise, and experience influence both problem interpretation, and solution proposition. Designers take as a starting point the malleability of the problem, thus providing space for (re)interpretation.

The existing concept of a wicked design problem, and its interpreted quality, may be of utility in positioning a distributed theory of design thinking. As problems are seen to be complex, design thinking supports the propositional exploration of possibilities, and the development of a design direction through problem framing. Adopting a distributed theory of mind, the designer distributes thinking through propositional representations of design intent towards future possibilities. In both wicked design problems, and distributed design thinking, propositional exploration of solution opportunities appears important. A distributed approach to design thinking provides a ready framework to further examine relationships between design problems, the construction and use of design representations in practice. Design problems are future focused. Thus, design thinking may require design representations as approximations that support future thinking. Adopting a distributed theory of mind may help explain the importance of design representations. If thought is distributed across designer and design representation, so the construction of and reflection upon representation provides opportunity to embed and test propositional solutions.

Because design solutions emerge from the designer's interpretation of the design problem, designers identify a most appropriate design solution, given their interpretation of the design problem. Nelson and Solterman (2012) suggest that a designer's aim is often to arrive at a solution that best satisfies the design problem, rather than to search for and identify a correct solution. The arrival at a solution to satisfy the design problem, requires exploration of opportunities. In applying a distributed approach to explore design thinking, various aspects may be identified and examined. For example, a distributed theory of mind positions as important the designer's skill and expertise in leveraging expressions of design intent to identify, evaluate and develop potential solution candidates.

The designer's expression of solution ideas is ubiquitous in design. From low-fidelity, thumbnail sketches, to technical illustrations and various prototyping approaches, design solution ideas are expressed and explored through their approximation throughout the design process. Adopting a distributed approach to explain design thinking, orientates towards the design representation's criticality in design thinking, as design thinking is situated between designer and design representation. In this orientation, rather than explained as externalization of thought, design representation is fundamental to design thinking. Thus, a distributed theory of mind may offer opportunity to bridge between design thinking and the applied nature of design Practice.

5. Conclusions

In this article I have positioned a distributed theory of mind as means to scaffold an explanation of design thinking in practice. I have touched upon the origins and evolution of the term design thinking, from its use within a body of work aimed at contributing to an explanation of design cognition, to more contemporary usage, describing a method to engage creative problem solving. I further limited the scope of my discussion to design thinking between designer and design representation within the situated activity of design.

Within this situated practice, I have examined the opportunity of a distributed theory of mind to help explain a relationship between designer, design representation, and the articulation of design intent towards solution possibilities. From ambiguity of expression, to detailed articulation of design intent, as thinking distributes across designer and design representation, so the type and character of representation implicates design thinking. Here I have attempted reveal the opportunity of a distributed theory of mind to contribute to an understanding of design thinking in practice.

I have discussed how design problems, their subjective quality, and a designer's propensity to reinterpret the design problem, may align with a distributed theory of mind. For example, distributed design thinking may contribute to explain how design problems are framed through the articulation of and thinking between designer and solution possibilities expressed through the construction of design representations. Rather than existing prior to thought, design representation occupies a central position within an explanation of design thinking.

With this article I have attempted to position a distributed theory of mind as opportunity to explore design thinking in practice. Contributing theory to help explain design thinking will support the design research community in providing tools and methods to identify design thinking, measure its impact, and understand its relationship to design practice. Design educators may consider curriculum in terms facilitating design thinking through representation; in consideration of various design tools, the skills require to use them, and the types of thinking they may facilitate.

Continuing to explore the potential of a distributed theory of mind as scaffold to understand design thinking in practice requires further study. Communities beyond design (cognitive science, psychology, philosophy of mind) will benefit from such research as it contributes to and extends distributed cognition theory, and the embodied mind approach to understanding human cognition more generally. There remains work to do in building theory to explain how designers think in practice. This article contributes by helping to lay the foundations for a distributed theory of mind as opportunity to bridge design thinking and the applied nature of design practice.

Funding Acknowledgement

This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2023S1A5A2A01075989).

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