The Dimensions of Thinking, Reflecting, and Knowing through Design

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Design is defined by complexity, in both its practical and theoretical applications, and positioned to address the developmental, situational, technological and societal challenges of the external world. The study and practice of design requires ways to select, frame, understand, address, and tackle the increasingly complex systems and contexts of design. This emphasizes the intangible attributes of design residing in thinking, reflecting, and knowing. Design capabilities have evolved with the development and engagement of various tools and frameworks to produce deeper reflections, meaningful contributions, and discourses of design. This chapter reviews the parameters of thinking-in-design, the reflective activities leading towards the design-of-practice, and the actions and applications resulting from knowledge-through-design. The shift of design, from traditional practice to systems-based thinking approaches, is further discussed against the dimensions of thinking, reflecting, and knowing in design.

Keywords: design theory, design thinking, reflexive design, design knowledge, design discourse

"Applied to the matter before us: we can learn thinking only if we radically unlearn what thinking has been traditionally. To do that, we must at the same time come to know it."
Martin Heidegger[1]

Design has extended beyond the boundaries of traditional practice, influencing new ways of thinking and interacting to inform social change, support collaborative experience and engage in human knowing. As global challenges present more complexities within selected contexts of study, the discipline of design has evolved to produce more powerful and meaningful impact. Design is no longer defined as a series of methods or means for problem-solving but articulated through the processes reasoning, producing its own ways of thinking and reflecting to generate the transferrable knowledge appropriate for adapting to the forces of change in a complex world. Each phase of design's progression has redefined the values produced, reevaluated the meaning of experience and recontextualized the frameworks through which we position design perspectives. This calls for a new way of utilizing, examining, and defining the impact of design through discussions of thinking-in-design, the production of design-of-practice through design reflexivity, and ways in which knowledge-through-design inform future cultures of design.

The discipline of design often deals with continually changing ambiguity and ill-defined parameters of issues, where the cognitive practice of thinking becomes a means for clarifying and shaping its systems and contexts of study. Through thinking, as a way of framing and contextualizing design, a reflective practice emerges to reify and critically evaluate emerging ideas, tools, processes and outcomes. These modes of design contribute to design knowing,

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[1] Heidegger, M (1968) What is Called Thinking? Harper & Row Publishers, New York.

where knowledge establishes a basis to adapt, inform, alter, and shift perspectives for future actions.

Design is exploratory in its ability to produce multiple frames and perspectives of a given situation, relying on iterative developments to question, probe, and assess its impact. As the tools, methods, and processes of design become more accessible and relevant beyond the scope of the design profession, there is growing importance in further defining the tacit and intangible skills of design. The formal applications of design, in theory and practice, require a deeper understanding and articulation of the broad skills and knowledge needed to address the increasing complexity of design issues.

THE STUDY OF DESIGN AGAINST A GROWING COMPLEXITY
Design has evolved across its neighboring disciplines to establish its applications and shift its studies from craft to interaction, experience-based, service-oriented, human-centered, and design thinking. No longer an insular discipline and practice, designers have had to work across multiple levels and adapt to the roles of analyst to synthesist, generalist and critic [1], developing the ability to dissect problem spaces through systematic processes and frameworks [2]. Figure 1 illustrates the positioning of the designer against complex design environments. The designer, as an individual actor or working within a team of actors, must learn to identify and understand problems within a given context of design to move through the various roles and stages of design.

Team effort is central to design, where designers assume the roles of generalist and leader to engage multiple perspectives and disciplines to realize a solution. Within such working groups, processes are required to solve the complex problems that are often layered within co-design approaches to synthesize initial ideas and solutions across a problem space. The criticality of a design lies in the ability to change frames when viewing a particular phenomenon, easing the cognitive load of design through divergent and convergent phases [2]. In the role of critic, the designer is able to reflect on the entire design process and reassess the original problem space to evaluate the effectiveness of the proposed outcome or solution. Design is, therefore, a practice of thinking that produces actions through reflective practices leading to the formulation of knowledge.

The challenging new contexts of design demand improved developments and tools to deal with changing situations and technologies, often relying on collaboration to build upon knowledge and methods for positive change. Simon's [3] definition of design emphasizes the function of devising a process, through courses of actions, to effect change from existing to preferred situations. This requires designers to establish clear frames and perspectives of action, particularly when dealing with the growing complexities of design problems where design relies on interdisciplinary knowledge to serve multiple needs against the widening scope of design impact [4]. Norman [5] supports the interdisciplinary conditions of design by arguing for the integration of a deep appreciation of people and the social sciences and deep understanding of science, mathematics, and engineering. Knowledge of peripheral areas, fields, and disciplines will add value to modern design, equipping designers with the ability to tackle root causes rather than the symptoms [6]. This reflects the call to move design from a focus on problem-solving activities towards a systems-oriented approaches in thinking.

As technologies continue to undergo rapid change, design plays an increasingly important role in responding through collaborative approaches, processes, and frameworks. Methods and systems need to evolve to develop deeper understandings through observation and contextual framing, supporting the iterative cycles of design. Design cannot be limited to the scope of problem solving but should be discussed as a practice beginning with the posing of strategic questions to establish propositions within a problem space that can be clarified through intentional and systematic exploration, experimentation, and experience. The experiential nature of design supports the processes of thinking, reflecting, and knowing to transfer thought into action, establishing and developing deeper understandings of design phenomena.

THINKING-IN-DESIGN
Design is a discipline of realizing solutions and impacting change through an exploration of problem and solution spaces, through a facilitation of communication across the problem-relevant environment [7]. The role of thinking, as a form of design practice explicated as *design thinking*, can be described as a cognitive style of problem solving, a general theory of design, or an organizational resource to drive innovation [8]. This section discusses perspectives of thinking-in-design beginning with the implication that design is a significant factor of shaping human experience, with the plurality of design as being applicable to different problems and subject matters in the reconsideration of problems and solutions [9]. Thinking-in-design is presented through a review of shared philosophies, changing perspectives, modalities, and implications.

The perspectives of thinking-in-design are outlined in Table 2, providing an overview of thinking as framing and understanding, synthesizing, rationalizing, communicating and articulating, and reasoning and processing. According to Buchanan [9], designers conceive subject matters in two ways on two levels as part of a process of discovery. Kolko [10] formalizes the synthesis process of design through an abductive sensemaking process, which often results in the emergence of themes and paradigms that shape future design activities. Lindberg et al [7] outline a normative approach to design that extends mono-disciplinary rationales into more flexible meta-rationales to build strategies upon a common ground. Sevaldson [11] argues that design thinking is inseparable from design practice within processes of synthesis, where complex information is organized through tentative, iterative, and heuristic development. Design produces different ways thinking that are fundamentally different from other disciplines, producing its own methods of reasoning and logic to identify patterns for action [12]. The cognitive orientation of design allows for descriptions, interpretations, and shifts in perspectives to be communicated [13]. Buchanan's [14] modes of thought build on the logic of pattern definition to suggest that systems fall into ways of interacting, thinking about the world, engaging phenomena to make sense of experience, and guide research and practical action.

Modes of thought shape human experience through creative inquiry by conceptualizing and clarifying the systems framing design complexity [14]. It is through the function of thinking that the study and practice of design are pushed beyond problem-solving to radically shift thinking-in-design as an important precondition to addressing the complexities of problem spaces [12]. Designers are tasked with intuitively and deliberately shaping design situations, positioning, and repositioning problems by identifying the views of participants and the issues

concerning them to develop relevance for further exploration and development [9]. This involves a high degree of thinking, producing a form of creativity that is innately and fundamentally human to present and provide experience [13]. The sensemaking process of synthesis activities allows for levels of thinking to manipulate, organize, and filter problem contexts [10], where visualization techniques provide the function of building networks through mapping and defining boundaries of systems [11], presenting pragmatic ways for the strategies of thinking-in-design to be made transferrable beyond the design discipline for an over-arching meta-disciplinary application [7]. The perspectives of thinking-in-design present the necessary and conscious act of making sense of complex design issues and problem spaces through varying modes of seeing, understanding, analyzing, describing, cataloguing, organizing, and planning courses of actions, shifting across intangible to tangible and implicit to explicit dimensions of design. Design thinking, therefore, can be thought of as a set of contingent and embodied routines that constitutes different ways of interacting with and within the sociocultural world [15].

REFLECTIVE PRACTICE
Design concerns human pathways that provide insights for the obstacles, problems, and possibilities of change [14], relying on processes of thinking that are embedded within the shifting from problem to solution spaces. The design experience embodies different levels of activity that extend thinking beyond abstract and theoretical dimensions to develop and formulate concrete ideas and practices. Designers have the ability to process information through sensory and tangible methods, using the conversational activity of seeing and drawing as a means to make sense of, understand, appreciate, and communicate [16] and, in this form of thinking through drawing and sketching, embodied representations of thought and knowledge are produced [17]. The reflective practice of design, as leading towards the design-of-practice, will be further discussed through an examination of reflection as a form of concrete thinking and design inquiry.

Reflection is a temporally suspended activity that occurs after an experience takes place, when its outcomes can be separated as part of the experience to be extracted, examined, and described. This posits that the act of reflection, of undergoing a continual evaluation through reasoning, reveals insights to establish an overall comprehension and understanding of the experience. Reflexivity, against the context of design, can be seen as the contemplation and negotiation of thought and understanding. This stage of design presents a form of internal dialogue where the conceptualization of a tangible design begins to materialize and take shape through reassessing, redefining, and recontextualizing all preconceptions of a design problem. The fast-changing nature of design contexts and issues demand periods of systematic reflection to fully contemplate the shifts from old to current situations and make informed decisions to alter future courses and plans, as illustrated in Figure 2. This diagram depicts design reflexivity as residing in the present, relying on the past experience to form future intentions along the dimensions of understanding. The recursive nature of reflexivity allows for all levels of thinking to be transferred through internal mechanisms of feedback and feedforward.

Reflection is a necessary condition of design thinking that affirms and modifies initial conceptions of a design problem in order to validate future intentions and implications. The reflective process of design can be seen as a temporal experience that mediates the space of

design inquiry, allowing the continual occurrence of systematic reflection to reinforce the positioning of design against external changes, levels of interaction and communication, and the formulation of courses of action.

Dewey [18] attributes meaning to experience, as an exacting mode of thought, when relating the acts of thinking, reflecting, and understanding. This implies that the whole of design experience, encompassing the development of a design process and related practices, would require systematic moments of reflection to allow meanings to be established as an experiential outcome. If reflective practice can facilitate a deeper understanding to transfer preconceptions of a design complexity into intentions by linking thought into action, there is a need to further define the role of systematic reflection as a key component throughout the design process leading towards the design-of-practice.

Thinking-in-design involves the embodied experience of contextualizing and framing the complexities posed by a problem space, making way for reflective activities and practices to further reify concepts and deepen levels of understanding. Design reflexivity positions the process of design as containing reflective conversations with the materials of a design situation [19], contributing to a continual and ongoing form of practice. Kimbell [15] defines four aspects of practice theory in terms of how they are understood, enacted and shaped through structures, materialized through objects, and transformed through interactions leading to conceptions of knowledge. This presents an alternative way of conceiving design activities through the following concepts:

- **Design-as-Practice:** the embodied, situated experiences of design that constitute a discursive practice through knowing, doing, and saying.
- **Designs-in-Practice:** the emergent nature of design enacted in practice and incomplete beyond the process and outcomes of designing.

Design-as-practice suggests that design, in its entirety, is representative of a practice. The outcomes afforded by *designs-in-practice* encompass the ongoing impact, interactions, and materialization of design. This leads to the question of when practice itself is designed and how does experience inform the *design-of-practice*.

Structure is necessary to give form to thinking and reflection, where the intangible qualities of building frames and formulating the boundaries of a design produce a discursive practice. Reorganizing, structuring, and formalizing these tacit experiences strengthen the notion of design-as-practice and enrich designs-in-practice. This leads to devising a design-of-practice as an extension of systematic reflection, translated through form, object, or process. Language is one manner in which the qualitative and dynamic processes of reflective practice can be articulated to present a new form of discourse [20]. It is through practice, that the processes of design are conceived and linked to other members, stakeholders, institutions, and end-users. Design practice is necessary to structure and understand how the tacit qualities of reflective practice can be transferred and made explicit.

DESIGN KNOWING

Against the ill-defined and ill-structured nature of design problems, the ways of thinking and reflecting inform a knowledge base for design. Cross [21] defines designerly ways of knowing as being embodied within codes that transform thoughts into words and objects, communicating the nonverbal experiences of design. According to Glanville [22], the designer

as actor assumes the role of observer-as-participant in making knowledge and constructing the ways of obtaining knowledge. Knowledge in design is broadly referenced as the ways in which the objects and outcomes of design lead to more the more active role of producing, organizing, and communicating ideas and solutions. The theoretical dimensions of design knowledge are often presented through categories that are based on the following polarities: tacit/explicit, abstract/concrete, subjective/objective, personal/universal. Although the epistemological and ontological foundations of design knowledge are often based in other disciplines and fields of study, the situated practices of design organize and formulate contextual knowledge to provide frames for understanding a particular phenomenon. This form of knowing serves as a precondition to experiential knowledge, which transforms and explicates the modes of thinking and reflection to be communicated and shared. Knowledge in design acts as the representation of experience, constructing and transmitting codes to be read and interpreted.

The design experience involves the active participation of designers and multiple stakeholders, transferring subjective and personal levels of knowing into tangible forms to prescribe future social situations and relations. Experience is necessary to refine and strengthen one's symbolic activities towards progress in thought [23], producing modifications to transform the natural ability to perceive and categorize the development of perception into regularities of knowledge [24]. Theories of knowledge, arising through the modes of symbolic interaction and being-in-the-world, lead to the production of self-knowledge that develops experience into perception and, eventually, generates design knowledge. Table 2 presents the varying perspectives of knowledge across the common theme that perception leads to the construction of knowledge through the modes of human activity and experience.

The theories of knowledge focus on the epistemological underpinnings of how knowledge is formulated, from where it develops into perception, and in what ways human knowing reinforces one's existence in the world. In contrast, design produces its own forms of knowledge when the tacit activities of thinking and reflecting are framed within specific contexts and transferred through representational forms. Polanyi [25] describes the symbolic operation of representing experience through the stages of primary denotation, reorganization, and reading of the result. This shifts the inarticulate elements of thought into explicit understandings, emphasizing the potential role of design knowledge and the subsequent impact of its finished forms when transferred and applied into action. Thinking-in-design generates the subject of *what* needs to be known or made known, as the boundaries of problem spaces and complexities are framed through design perspectives, theories, and approaches. As an extension of reflective practice, the experience of design practice lends itself to articulate *how* knowing is developed. This concept of knowing *how* is what formulates knowledge-through-design.

Buchanan [26] describes experience as being found in the relationship between the individual and environment, not in the internal process of accumulating sensations and perceptions. If knowledge is contingent on the value and quality of experience, this definition of experience positions the role of design as creating environments within which human intent moves into

interaction, producing meaning as the fulfillment of original intent. These environments can be created through deeper purposes of unity in design, clarifying human experience as:

- **Practical action:** the simple, overt physical gestures used to gain access to a product, fulfilling the purpose of the experience
- **Intellectual Understanding:** the information or obstacles to the cognitive and intelligent understanding of action
- **Emotional Engagement:** the feelings arising from interaction with an environment

Design knowledge can be comprehended across different frames and domains to embrace, enlarge, internalize, transmit, shift, recontextualize, and transform thought into action across the dimensions of knowing [27]. Knowledge, as it shifts from tacit to explicit, requires new frames and contexts for its values to be realized. Buchanan [28] defines four orders of design as a place for rethinking and reconceiving the nature of design across the professions of graphic, industrial, interaction and systems design. The four orders of symbols, things, actions, and thought are shown across the explicit/concrete and implicit/abstract dimensions of design in Figure 3. As design practice moves away from analytic and synthetic aspects towards the intentional placements and situations of use defined by the four orders, design assumes the mediating role of negotiating between design intent and user expectation. These new interactions and experiences require different kinds of knowledge and suggest that while design produces knowledge stemming from and relevant for other disciplines and fields, design knowledge is the knowing that materializes, transforms, transfers, and acts *through* design.

Design knowledge, according to Manzini [29], is the knowledge that can be used by designers and non-designers in their processes of designing and co-designing. The cognitive functions of knowing materialize through tangible forms, such as visions for strategic discussion, proposals for integration, and tools for understanding and implementing. This emphasizes that design knowledge needs to be made communicable and clearly expressed to be applied and used by others.

Design ability can be defined as a form of intelligence and a multi-faceted cognitive skill [30]. However, Manzini [29] argues that traditional design knowledge accumulated through the implicit knowing of professional design is no longer sufficient to deal with the plurality of design that is influenced by systems of change and dynamic problem contexts. Design knowledge needs to become more robust in the ways that it is ontologically categorized within the contexts where design can produce more meaningful and sustainable impact. This requires different networks of actors to work together, allowing the various domains and attributes of design knowledge to be continually shared, exchanged, transferred, transformed, altered, and applied.

THE IMPLICATIONS OF DESIGN THINKING, REFLECTING, AND KNOWING
There is clear shift occurring in the areas of design study, education, and practice. The forms of design that conform to traditional skills and crafts will represent the past while design comprising the ability to lead and transform future design requires further knowledge through the exploration of technology, social sciences, and the complexities of the world [5]. Future design will transform practice through modes of thinking, emphasizing the focus of design on people and human-centered approaches when dealing with complex problems.

This will contribute to a body of knowledge that builds upon all the knowledge of all specialized fields.

Manzini [31] argues that design has shifted from a focus on objects toward ways of thinking and doing as part of the human-centered approach. Against this implication, that all design activities are forms of co-design and involve groups of multi-skilled actors, the following three meanings of design can be established:

- **Diffuse Design:** the natural human ability to adopt a design approach, resulting from critical sense, creativity, and practical sense
- **Expert Design:** refers to the professional designers who possess specific design skills and culture
- **Co-Design:** the overall design process resulting from interactions spanning various disciplines and stakeholders

These three meanings of design represent what Manzini refers to as emerging design, which establishes a dialogic cooperation where the willingness to listen and converge towards a common view results in collaboratively obtained outcomes.

Dorst [2] presents two issues confronting design within complex situations: (1) the starting point is difficult to discern, making it challenging to interpret a problem situation and (2) the interrelated relationships within systemic complexity further complicate the shaping of appropriate ways forward. Adopting an exploratory, reflective practice for design presents a new paradigm for future design that is highly iterative and intentionally indeterminate. This allows for a flexible system of design marked by resilience and adaptability, reinforcing the dialogic and dialectic processes of design.

Meyer and Norman [6] outline eleven design challenges into the four cumulative groups of Performance, Systemic, Contextual, and Global Challenges, which define the future of design and call for new ways to address the different levels of design problems. The first group, *performance challenges,* can be addressed through traditional skills and knowledge. *Systemic challenges* require systems thinking skills, multidisciplinary knowledge, and management and leadership training. *Contextual challenges* are situated challenges that necessitate a form of co-design, allowing the community to be involved in the process. Finally, *global challenges*, is a team effort that may call on design skills but will involve bottom-up collaborations and knowledge across all relevant domains. The eleven challenges of design are outlined below in Table 4.

This chapter has discussed design as relying on experiences to produce the dimensions of thinking, reflecting, and knowing in design. These varying perspectives and theories of design reveal current gaps in research and practice, suggest areas in which professional designers can contribute to the theorizing of current and professional practices, and propose future areas where the frameworks and models of design research can aid in formalizing design activities. There is a clear shift in design that is driven by the interconnectedness of human experience, moving discourses from traditional practice towards the ambiguity posed by the systemic challenges of complex design problems. The discussions throughout this chapter have examined the current challenges of design amidst the growing complexities posed by design problems, leading to a review of how design constitutes thinking-in-design to frame concepts and problem spaces, presents moments of reflection to reify and deepen

understandings of the design context towards the design-of-practice, and formalizes experience to produce knowledge-through-design. The dimensions of thinking, reflecting, and knowing in design are illustrated in Figure 4.

Design shifts thinking, reflecting, and knowing across the situated practices involving the mind, body, things, structures, knowledge, processes, and agency. In consideration of the ways that design knowledge and its practices are being utilized and applied in non-design fields, there is much to be defined in the agency of design knowledge against the social, co-created, co-designed structures of design collaboration. This proposes future discourses of social design and the role of design in multi-stakeholder collaboration, furthering research on the implications of decolonizing and democratizing design knowledge, building on the implications of Manzini's [29] call for new design knowledge that is explicit, discursive, transferrable, and accumulative.

CONCLUSION

Design problems are growing in complexity and clarifying the ill-defined and ill-structured problem spaces requires intentional levels of thinking. The mode of shifting design thinking from problem definition to a solution focus relies on reflexivity, giving form and structure to deeply understanding the positioning of design practice. Reflective practice reiterates the frames and perspectives of thinking to deepen understanding, reposition the role and function of design, and transfer thought into action through the design-of-practice. Design produces its own knowledge through designerly ways, which serve as representations of contextual and experiential knowing. Knowledge-through-design provides the premise for design to produce explicit, discursive, transferrable, and accumulative forms. The dimensions of thinking, reflective, and knowledge in design have been examined against the paradigmatic shift of design from traditional practice to systems-led domains that require more robust and resilient implications of design.

This chapter has reviewed and presented the experience of design and the entirety of the design process as being developed through the dimensions of thinking, reflecting, and knowing. Design is exploratory in nature and relies on the ability to organize, frame, question, and infer through the use of various tools, models, frameworks, and practices. The implicit and subjective activities of design have been discussed throughout this chapter to clarify how the processes of thinking, reflecting, and knowing transfer the tacit experiences of design practice into explicit forms to be communicated, discussed, and challenged. Broad theories and philosophies of design have reviewed the interdisciplinary roots of design across the fields of art and science, presenting the areas in which design can continue to inform and contribute to its own domains of theory and knowledge. As the future study, practice, and application of design is moved into highly ambiguous, inarticulate, and complex problem spaces, the role of design needs to be re-examined to identify the gaps in theory, practice, research, and knowledge.

CORE MESSAGES

- **Thinking-in-Design:** focuses on *what* needs to be known or made known against problem spaces through the development of frames, organization of information, and problem identification.

- **Design-of-Practice:** articulates *how* knowing is developed through the development of reflective practice, reifying the concept developed through thinking-in-design and deepening the understanding of the problem space to devise future courses of action.
- **Knowledge-through-Design:** determines *where* knowing needs to be transferred, shifting all processes of thinking and reflecting into explicit, tangible, and communicable forms.

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TABLES

PERSPECTIVES OF THINKING IN DESIGN	
Wicked and Indeterminate Design Problems *(Buchanan, 1992)*	
General Level	The designer holds a broad view of design and the scope of application
Particular Level	The designer begins with a quasi-subject matter, as an indeterminate subject
Philosophies of Synthesis *(Kolko, 2010)*	
Sensemaking	An action-oriented process to integrate experiences into understanding
Abduction	An inference or intuition that is directly aided and assisted by personal experience
Descriptive-Analytic Design *(Lindberg et al, 2010)*	
Paraphrasing	Formulate and re-formulate the design question or task
Restriction-Free Thinking	Avoid personal judgments and develop shared judgments
Meta-rationale	Diversity should be encouraged to move in maximized domains of competence
Conceptual Frameworks of Systems Oriented Design *(Sevaldson, 2011)*	
Design Thinking & Design Practice	Design thinking is inseparable from design practice Synthesis is the central aspect of design thinking
Visual Thinking & Visual Practice	Heuristic process of visualization, descriptive and generative diagramming Communicates information through participation and collective production
Systems Thinking & Systems Practice	A general framework to deal with complexity Ability to address multiple aspects and generate holistic and synergistic responses
4 Ways of Design Reasoning *(Dorst, 2015)*	
Deduction	Shifting knowledge, patterns of relationships and observations from cause to effect
Induction	Discovering patterns in relationships through observation to infer and propose predictions
Normal Abduction	Conventional problem-solving to clarify the problem scope
Design Abduction	Defining key concepts and clarifying the problem space by employing a design process
Systems View of Creative Design Thinking *(Mononen, 2017)*	
Creativity in Design	Process of developing individual perception through human capabilities
Creativity in a Systems View	Produces a network of interactions to form new functions and innovations
Modes of Thought *(Buchanan, 2019)*	
Construction	Process of interacting with the surrounding environment
Discrimination	Process of thinking about the world to formulate interpretations
Resolution	Process of making sense of the experience of phenomena to resolve problems
Assimilation	Process of devising action through an approximation of truths

Table 1. Perspectives of Thinking in Design

CLASSIFICATION OF KNOWLEDGE		
Author	Mode	Outcome
THEORIES OF KNOWEDGE		
Cassirer (1944)	*Symbolic interaction*	Understanding the world Codes of communication Generate meanings
Polanyi (1962)	*Symbolic interaction*	Personal knowledge as tacit & subjective Generate meanings
Hudson & Ozanne (1988)[i]	*Symbolic interaction*	Social construction of reality Codes of communication Generate meanings
Popper (1994)	*Sensory ability*	Ability to perceive Understanding the world
SELF KNOWLEDGE		
Scheler (1973)[ii]	*Feedback*	Ability to perceive Self-expression Organizing the world
Csikszentmihalyi & Rochberg-Halton (1981)[iii]	*Feedback*	Ability to perceive Self-expression Codes of communication
Heinamaa (2012)[iv]	*Sensory ability*	Ability to perceive Self-expression
DESIGN KNOWLEDGE		
Cross (1999)[v] & (2000)[vi]	*Experience*	Creation & maintenance of the artificial world
Friedman (2000)	*Feedforward & Feedback*	Experience Ability to perceive Belonging in the world Reflective practice
Hoadley & Cox (2009)[vii]	*Experience*	Creative processes Meta-knowledge
Narvaez (2000)[viii]	*Social Influence*	Projective ability Design thinking Dialectic relationship between designer & user

Table 2. Classification of Knowledge

[i] Hudson LA, Ozanne JL (1988) Alternative Ways of Seeking Knowledge in Consumer Research. Journal of Consumer Research 14: 508-521.

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KNOWLEDGE-THROUGH-DESIGN		
Attribute	**Domains of Use**	**Function**
Explicit	*Designers, Individuals, Communities, Institutions*	To be made known and cognizable To be clearly expressed through a form
Discursive	*All relevant persons/contexts*	To stimulate discussion To negotiate and establish shared understanding To explore propositions and possible strategies
Transferrable	*Designers, Design Groups, Education, Research, Communities of Practice*	To be applied through processes and actions To be formalized as practice To propose tools, models and frameworks
Accumulative	*Researchers, Future Contexts of Design*	To build research and future knowledge To theorize design practice

Table 3. 5 Types of Knowledge-through-Design (Adapted from Manzini, 2009)

11 CHALLENGES OF DESIGN		
Category	**Description**	**Challenges**
Performance Challenges	*Relating to what designers must do*	1. Design acts on the physical world and on the linked world of intangibles 2. Design addresses human needs and desires (specific and abstract) 3. Design generates the tangible and intangible built/social environments
Systemic Challenges	*Relating to addressing the entire system and not just a single part*	4. We live in a world marked by ambiguous boundaries between artifacts, structures, systems and processes 5. We work in a world of large-scale social, economic and industrial frames 6. We design for a complex environment of ever-shifting needs, requirements and constraints 7. We design for a world in which intangible content often exceeds the value of physical substance.
Contextual Challenges	*Relating to dealing with complex systems that are strongly affected by their environment, local culture, and political concerns*	8. The projects, products, and services we design often cross the boundaries of other organizations, stakeholders, producers, and user groups 9. The projects, products, and services must meet the expectations of other organizations, stakeholders, producers, and users 10. These projects, products, and services must meet the demands at every level of production, distribution, reception, and control
Global Challenges	*Relating to dealing with complex sociotechnical systems*	11. Address the major social issues facing the world

Table 4. The Challenges of Design (Adapted from Meyer and Norman, 2019)

FIGURES

Figure 1. The Roles of Design (adapted from Friedman, 2003)
Figure 2. Reflective Practice in Design
Figure 3. The 4 Orders of Design (Adapted from Buchanan, 2001)
Figure 4. The Dimensions of Design