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Systems Thinking and Design Thinking: The Search for Principles in the World We Are Making

Abstract While the concept of system has been part of design theory and practice from the beginning of the discipline, there is renewed interest today in the relationship of systems thinking and design. After reviewing the sources of ambiguity in the commonplace definition of the concept, we can identify four distinctly different interpretations of what a system is, how it operates, and the common purposes that the systems may serve. This leads to a consideration of the value and limitations of systems thinking and systems analysis for design. Systems analysis provides no clear identification of the problems that designers may address. Instead, design turns away from the complexity of situations and surroundings and toward the obstacles and problems faced by human beings in concrete situations, creating environments that may support and improve the quality of human experience. Design is the transformation of surroundings into environments for human experience. We have reached a point where it is important to begin a discussion about the principles of design and the environments that we seek to create.

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Our time is fraught with concern about the principles upon which many of the major systems in our lives are grounded, and the design community is sensitive to concerns about the degree of design's involvement in those systems. How can designers navigate the growing complexity that we face through the development of artificial intelligence, the expanding place of information technology in daily life, and the increasingly limited role that design is given in making fundamental decisions about those systems? There are no simple answers, but the best place to begin is with an assessment of what the idea of systems has meant in design, and where the designer's ideas about systems may lead. The goal of this article is to discuss some of the fundamental ideas that stand behind the concept of "systems" in design. It is not intended to be a review of the literature that has arisen around the relatively recent systemic design movement, nor is it intended to be a critique of the trend or movement as it now stands, still in a formative stage through the explorations of the relationship between systems thinking and design in conferences such as "Relating Systems Thinking and Design."[1] Rather, it seeks to identify the variety of ways in which the concept of systems is relevant or has been understood in the design community, with recognition of the pluralism of approaches that are valid and useful for design theory and design research. It also suggests some of the implications that students, designers, researchers, and design theorists may need to consider as the field moves forward in addressing the wicked problems at the center of the complex environments within which design operates today and within which human beings live and play, work and learn. In this way, we may gain a better understanding of the relationship between systems thinking and design thinking as well as new ways to think about systems approaches in design.

The Concept of Systems in Design

The concept of system has been part of design theory and practice from the beginning of the field and the establishment of its diverse disciplines and practices. Sometimes the term is simply implicit, because other equivalent terms such as structure, form, functionality, organization, or a wide variety of others take its place. An example is Herbert Simon's "The Structure of Ill-structured Problems,"[2] where the author discusses the status of design problems in the "problem solving systems of artificial intelligence." Other times the term is explicit in one or another variation, such as in John Chris Jones's discussion of "A Method of Systematic Design"[3] or Bruce Archer's "Systematic Method for Designers."[4] There is nothing subtle or esoteric in the exploration of systems in design. This is evident in a commonplace definition of a system:

> A system is a relationship of parts that work together in an organized manner to accomplish a common purpose.

Every designer, whatever his or her philosophy, school of practice, or approach to design, will recognize this as a characterization of (1) the beginning perception of a problem for design inquiry; (2) a product; (3) the methods of design practice; or (4) the strategies, contextual engagements, and economic, social, and cultural interdependencies that must be addressed in theory and practice. Every product is a system of parts working together to accomplish a common purpose, whether in the graphic display of typography, images, color, and pattern in a poster; the integrated workings of a physical artifact; the sequence of planned activities, communications, and exchanges of a service or any other human interaction; or the complexities of dynamic and evolving organizations, environments, and systems.

1 The series of conferences is presented in descriptive literature. "The Relating Systems Thinking and Design Symposium series started in Oslo in 2012 with RSD1. The symposium series has the intention to promote and foster the emerging dialogue of rethinking systems approaches in design." Systemic Design, "RSD Symposia: Proceedings," accessed May 7, 2019, https://systemic-design.net/rsd-symposia/. This work is grounded, of course, on a much larger body of literature in general systems theory identified by Kenneth Boulding in 1956 and the related work in social systems, organizational systems, or information systems upon which the systemic design movement is based. For a recent example, see Gary S. Metcalf, ed., *Social Systems and Design* (New York: Springer, 2013).

2 Herbert A. Simon, "The Structure of Ill-Structured Problems," in *Developments in Design Methodology*, ed. Nigel Cross (New York: Wiley, 1984), 145–46.

3 J. Christopher Jones, "A Method of Systemic Design," in *Developments in Design Methodology*, ed. Nigel Cross (New York: Wiley, 1984), 9–32.

4 L. Bruce Archer, "Systematic Method for Designers," in *Developments in Design Methodology*, ed. Nigel Cross (New York: Wiley, 1984), 57–82.

More than this, designers have long recognized that products function within broader systems and systems of systems. This was true in the founding of the Deutscher Werkbund in 1907, the birth of the Bauhaus that followed in 1919, the further development of the New Bauhaus in Chicago in 1937, the establishment of the Hochschule für Gestaltung Ulm (HfG Ulm) in 1953, and the continued development of design schools around the world. In the language of systems analysis, products are sub-systems within a hierarchy of larger and larger contexts and of larger and larger systems.[5]

Walter Gropius expresses this idea in *The Scope of Total Architecture*, where he explains the cultural significance of the creation of the Bauhaus as a constructive response to the devastation of the First World War. The total architecture to which he refers is an *architectonic art*, where "architectonic" means not architecture as a particular branch of design but a comprehensive principle of all design, a system of arts and methods more in line with the original meaning of architectonic in philosophy as an expression of an organizing principle.[6] In turn, he refers to the collaboration of individuals as parts of a whole working together in coordination toward a common purpose—a system of methods in practice. Finally, the system of working in coordination *symbolizes* (Gropius' word) the cooperative organism of society, the further system that surrounds and conditions the work of design.

> "I saw also that to make this possible [preparing a new generation working with modern means of production] would require a whole staff of collaborators and assistants, men who would work, not as an orchestra obeying the conductor's baton, but independently, although in close co-operation to further a common cause. Consequently I tried to put the emphasis of my work on integration and co-ordination, inclusiveness, not exclusiveness, for I felt that the art of building is contingent upon the co-ordinated teamwork of a band of active collaborators whose co-operation symbolizes the co-operative organism of what we call society.... Thus the Bauhaus was inaugurated in 1919 with the specific object of realizing a modern architectonic art, which like human nature was meant to be all-embracing in its scope."[7]

Gropius recognized that all of the branches of design, working together, offered a way to build better systems to withstand the destructive elements of human behavior and the outdated customs revealed by the First World War. There are legitimate critiques of the Bauhaus vision and its consequent results, but any critique that fails to recognize the context within which the Bauhaus operated is a weakened critique.

László Moholy-Nagy similarly expressed the idea of systems in "Design Potentialities," his foundational expression of ideas at the New Bauhaus in Chicago.[8] He discusses the importance of understanding design and the products of design in the context of natural systems, technological systems, biological systems, and a variety of social systems with their economic, psychological, and sociological requirements. Relationships with all of these systems, he explains, reveal the components of a functional design. The concept of functionality—sometimes criticized today as too narrow—was not a narrow concept for Moholy-Nagy. It was a systems concept with many dimensions, as his statement indicates. Moreover, the theme of systems can be found in the programs and invited lectures at the HfG Ulm or in the work of individuals such as Herbert Simon and the diverse participants in the Design Methods Movement of the 1960s. From the beginning of design, systems and systems thinking have been a relevant and often lively topic for discussion, placing the practical work of designers in larger contexts.

5 "Objects to be designed must not be seen in isolation but in conjunction with the contexts in which they are to be placed. Above all, the designer should always step back and take a critical look, at the thing he is working on: how you design has a decisive impact on the product." Horst W. J. Rittel, "The HfG Legacy?," in *Ulm Design: The Morality of Objects*, ed. Herbert Lindinger, trans David Britt (Cambridge, MA: MIT Press, 1991), 119; see also "The Pursuit of Reasons and Systems: Editorial Discussion," in *Ulm Design: The Morality of Objects*, ed. Herbert Lindinger, trans David Britt (Cambridge, MA: MIT Press, 1991), 76–79.

6 From the beginnings of philosophy, the terms *arche* and *principium* refer to the principles that are the origin, cause, or organization of what exists. The nature of *arche* is variously interpreted in the pluralism of early philosophy.

7 Walter Gropius, *Scope of Total Architecture* (New York: Collier Books, 1970), 19–20.

8 L. Moholy-Nagy, "Design Potentialities," in *Moholy-Nagy: An Anthology*, ed. Richard Kostelanetz (New York: Da Capo Press, 1970), 81–89.

It is true that the agenda of such institutions involves a mixture of successes and failures that are open to critique. What this demonstrates, however, is not the failure of designers to grasp the significance of systems or systems thinking or systems analysis, but rather the ongoing pluralism of approaches in the exploration of design and systems as new insights are gained and as new creative possibilities emerge.[9] Further, it demonstrates the danger of philosophical entrapment: becoming trapped in one or another theory of systems, ignoring the insights that may come from considering other perspectives. One of the great strengths of design in the past century is the central focus on what is concrete in human experience – the issues and problems that human beings face in their lives and what human beings can create and make in products to overcome those issues or problems – without excessive ideological concern for differences of theory and philosophy among designers and their movements or schools. Design is, in a sense, like the natural sciences. Individual scientists hold many different principles regarding natural phenomena, yet science itself flourishes because of the overriding focus on understanding the phenomena under investigation. There is more concern for insights into phenomena that may come from different principles of inquiry than disputes about which principles are true, correct, or valid. Similarly, design flourishes when a pluralism of approaches is appreciated for the different insights that they bring into common problems of making and serving the needs of human beings.[10]

However, the concept of system has attracted renewed interest in the early decades of the twenty-first century among design theorists and designers. There are several explanations for this renewed interest. Old systems are showing signs of strain, sometimes breaking down with the increase of population around the world. Systems that were designed for one scale of operation are now required to support vastly larger scales of demand. At the same time, new technological systems supported by artificial intelligence offer innovative opportunities for "interface experience" in our human relationships and in our relationship with the world of artifacts and nature. The web of socio-technical systems is evident around us, and designers are called upon to smooth the edges and refine new products that may serve the human community more effectively.

Of course, these are the utilitarian reasons for the designer's interest in systems. But there may be deeper reasons for our interest in systems today. Have our systems broken down simply because of the changing scale of challenges that they were designed to meet or are they breaking down because the principles upon which they were originally designed are no longer perceived as relevant for the complexity, opportunities, and aspirations of contemporary life? More troubling, we may wonder if designers and the organizations for which they work have abandoned the principles that have governed systems in the past. Public discussion of the problems of the digital platforms of social media is only one example. More generally, has there been a loss of principles in the design and development of systems in our time? There is some evidence that our largest technological systems and the organizations responsible for those systems no longer reflect the values and purposes that once guided and governed their early growth. Our new interest in systems may reflect a growing awareness that we cannot ignore or defer attention to the wicked problems that lie at the core of human-made systems, where values and purposes are essentially contested among interest groups and are often in deep conflict.[11] We discuss systems today in the design community because there is unease and uncertainty about the principles that are the basis of systems and perhaps even greater uncertainty about the principles of design itself. Designers recognize the need for creative inquiry to explore the nature of systems and the principles that govern them.

9 A recent example of changing perceptions of design problems is found in Bruce M. Tharp and Stephanie M. Tharp, *Discursive Design: Critical, Speculative, and Alternative Things* (Cambridge: MIT Press, 2018).

10 "What is distinctive about the sciences, according to McKeon, is not that they do or do not exhibit a plurality of approaches, but that they make better use of this plurality than other disciplines.... [T]he sciences rather than philosophy provide the best models of pluralistic inquiry." Walter Watson, "McKeon's Contributions to the Philosophy of Science," in *Pluralism in Theory and Practice: Richard McKeon and American Philosophy*, ed. Eugene Garver and Richard Buchanan (Nashville: Vanderbilt, 2000), 186.

11 Alexandra Jayeun Lee, *Resilience by Design* (New York: Springer, 2016). An architectural perspective on systems thinking and design, addressing the issue of wicked problems first described by Horst Rittel and Melvin M. Webber. This book briefly explores the intersection of systems thinking and the design methods movement, but the account of the movement perhaps slightly distorts the history of design and the issues and significance of the design methods movement. See Horst W. J. Rittel and Melvin M. Webber, "Planning Problems are Wicked Problems," in *Developments in Design Methodology, ed. Nigel Cross* (New York: Wiley, 1984), 135–44. The original account of wicked problems by Rittel and Webber is grounded in architecture and urban planning. For a different account grounded in design and design thinking, see Richard Buchanan, "Wicked Problems in Design Thinking," *Design Issues* 8, no. 2 (1992): 5–21, DOI: https://doi.org/10.2307/1511637.

Ambiguities of the Concept of Systems

Serious consideration of the relationship between systems and design should begin with recognition of the deep ambiguity in the concept of system itself. Of course, many discussions of systems and systems thinking quickly pass over the ambiguity of the term, preferring instead to move on to one or another favored theory – and there are many favored system theories. Nonetheless, recognition of the ambiguity is important if one is to understand the diversity of perspectives that are evident in literature and in practice. The ambiguity is revealed in any of the commonplace definitions of a system. Commonplace definitions serve the purpose of providing a general sense of a term that allows discussion to move forward even among competing approaches. Typically, such definitions identify the places of ambiguity where differences of interpretation arise, leading to different understandings and directions for inquiry and more focused definitions of systems. There are four issues of ambiguity and potential controversy in the study of systems (Figure 1).

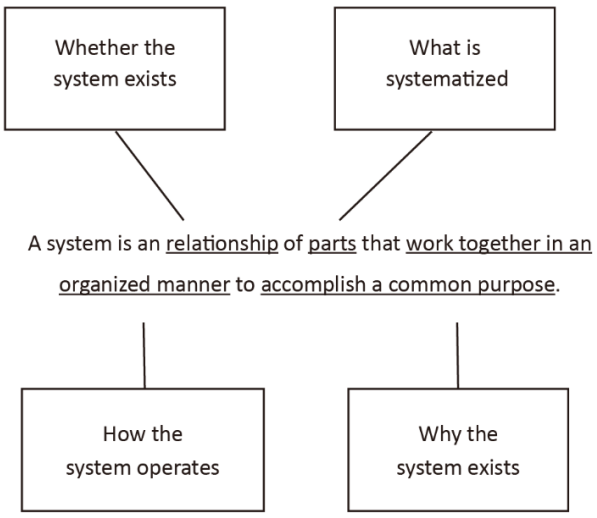

Figure 1 Strategic ambiguities in the definition of systems. Copyright © 2019 Richard Buchanan.

The first issue is *whether a system exists*. The evidence of existence begins with the perception of a relationship between parts and wholes in our surroundings. Of course, we do not experience the wholeness of the system, but we may recognize a relationship between the phenomena that we perceive and experience. The phenomena may be selected from the vast array of what is given to us in our encounters with the world. The selection may be from symbols and actions, or physical things and emotional reactions to things, or the ordered sequence of events and occurrences around us, or the thoughts and ideas that humans form in reflection or action. Any of these may be the focus of attention and the source of data. The potential for existence of the *wholeness* that characterizes a system – moving from a diffuse and indeterminate situation to a potentially unified whole – is the beginning of inquiry.[12] The issue of existence may not appear controversial, because there is general agreement that we are concerned with systems and there is some general agreement about the subject that is the focus of attention. Yet, this issue is the deepest and most controversial in the study of systems and design, because it is the issue of principles as they emerge in theory and in practice. Is a system a material assembly? Is it an arbitrary set? Is it an organic group? Is it a harmonious and orderly condition? These terms represent different principles that may explain the wholeness of the relationship that we initially experience. Furthermore, this issue is often accompanied not only by a preliminary or potential principle, a hypothesis about the indeterminate situation, but also by a discussion of the origin of systems.

12 "Inquiry is the controlled or directed transformation of an indeterminate situation into one that is so determinate in its constituent distinctions and relations as to convert the elements of the original situation into a unified whole." The "unified whole" in this definition of inquiry, of course, signifies a principle that emerges from research or creative practice, and the principle, in turn, signifies an organized system. John Dewey, *Logic: The Theory of Inquiry* (New York: Holt, Rinehart, and Winston, 1938), 104–5.

The search for an origin may involve distinctions among the natural, artificial, and spiritual. In turn, the artificial may involve a variety of possible origins, shaped by human needs and desires, different political or economic forces, spiritual insight, or any of a vast array of human motivations. Since a principle is both a beginning and an end, a discussion of origins is entirely appropriate.

The second issue is *what is systematized*. Discussion moves from evidence of the existence of wholeness and the origins of systems to a consideration of the parts that are to be systematized. This second issue is answered with the identification and enumeration of the parts or components of the system. At this stage the nature of parts, itself, is a place of ambiguity. The parts may be physical or material parts, but they may also be objects, people, actions, products, ideas, beliefs, practices, or many other components. It is important to recognize that whether one speaks of parts, elements, components, units, or some other term, the list of possible kinds of parts is extensive and quite diverse. Understanding the relevant parts of a potential system reveals the nature of the systems inquiry that is undertaken and it may lead to better understanding of changes that can alter the outcome of a dynamic system.

The third issue is *how the components work together in an organized manner*. The phrase "work together" indicates the dynamics of change in the situation, and change reveals the interdependence and interrelationships of the components as they interact. This leads to a discussion of how the system operates. Do the components work together by mutual influence, reciprocal action, dynamic exchange, or some other form or process of interaction? This issue concerns the activity of the system. Many of the commonly discussed aspects of systems emerge around this issue. Is the system complex or merely complicated? What are the emergent properties of the system that belong to the wholeness of the system rather than the individual properties of the parts? Is there a hierarchy in the system, with distinguishable sub-systems? Is the system open or closed? Is the system resilient in the face of internal or external disturbance? In turn, this issue leads to discussion of the behavioral properties of the system as a whole. Is it a self-organizing system? Is it adaptive? Does it evolve? The ambiguity lies in how we explain the process of change and the workings of the system.[13]

The fourth issue is *why the system exists*. What purpose does the activity of the system serve or achieve? What is the function, goal, value, or principle that unites the system as a whole? Of course, this is where the distinctions among natural, artificial, spiritual, and philosophical systems become most significant. If the system is human-made, what is the intent behind the system? Is there real intent or only chance and contingency in its operation? Is the intent adequate for the long-term sustainability of the system? What are the criteria for a successful system or system intervention? Is the system fair, just, and supportive of human beings and their inherent dignity? Questions of value and principle become complex in this issue; the difference between *first principles* and *relative first principles* often becomes the terrain of philosophical, ethical, and political controversy.[14]

Systems and Modes of Thought

The commonplace definition of systems and the ambiguities of the definition are only the beginning of a discussion of systems. The discussion leads to more refined definitions, suitable for inquiry in a variety of disciplines and addressing a wide range of phenomena. Among the various definitions, there are several clusters of definitions that recur in the literature, in various dictionaries, and in specific disciplines. In turn, these definitions are anchored by a small number of key terms that, themselves, recur individually or are arranged in patterns. Some of the key terms

13 A useful example of the dynamics of change in cultural systems is a discussion of the relationships among what is residual, dominant, and emergent in the dynamics of evolving cultural systems. See Raymond Williams, "Dominant, Residual, and Emergent," in *Marxism and Literature* (Oxford: Oxford University Press, 1977), 121–27.

14 First principles are sometimes referred to as "absolute" first principles because they are unconditional, with no prior or higher principle standing above them. Relative first principles are also first principles, but they are conditioned by their circumstances and find their deeper grounding in other principles that stand above, behind, or below them. An example of a relative first principle is "originality" in a design work. Originality is a principle that stands above many methodological principles of design, but it typically has deeper grounding in the principle of art in human expression or truth in expression or some other first principle. See Walter Watson, *The Architectonics of Meaning: Foundations of the Pluralism* (Chicago: The University of Chicago Press, 1985), 101. In contrast to Aristotle, Plato does not offer absolute first principles in his work. Rather, principles emerge in an ongoing dialectic that leads to higher syntheses and more "likely stories" about the ontological principles of existence as dilemmas are encountered and resolved in discussion. The principles that emerge in the Platonic dialogues are relative first principles, since they are stepping stones in the dialectical search for even higher principles, more comprehensive principles.

are: arrangement, assembly, aggregate, set, group, organization, scheme, plan, and condition. These terms are often combined or divided in an arbitrary and sometimes chaotic mixture. This is evident in the variety of dictionary definitions of systems. In the *Oxford English Dictionary*, for example, a system is defined as "a set or assemblage of things connected, associated, or interdependent, so as to form a complex whole."[15] Later in the *OED* list of definitions in general or special usage, system is also defined as a group, scheme, plan, and so forth.

Dictionaries are a useful source of commonplace definitions, provided one is careful to look beyond the book definitions and look toward the ideas that stand behind and lead to further definitions. Dictionaries are social and cultural documents, reflecting different usages and interpretations of terms that have emerged over a long period of time in the human community. Furthermore, dictionary definitions often reflect different ways of thinking and the philosophical assumptions that stand behind common usage. Dictionaries capture the range of usage and opinions held by people – ordinary and expert – about the topic or concept being defined; they provide a glimpse into the pluralism of ideas that have developed over the years in discussions.

The definitions of systems fall into a pattern of four broad clusters, each represented by a key term or theme. Moreover, there is logic in the pattern of definitions. Each definition is based on a different *mode of thought*: a way of interacting with our surroundings and environment; a way of thinking about the world; a way of engaging phenomena and making sense of what we experience; a way of guiding research and practical action. Modes of thought are discussed by philosopher Richard McKeon as a way of distinguishing the meanings of important terms that occur in practical action and theoretical reflection. He distinguishes four modes of thought, each based on a different philosophical assumption. Moreover, he argues that the modes of thought are mutually exclusive and formally exhaustive of possibilities. He describes the modes of thought in this way: "Even in non-technical considerations of thinking, four modes of thought may be distinguished: it is a process by which parts are put together, or englobing truths are approximated, or problems are resolved, or arbitrary formulations are interpreted."[16] McKeon names the four modes and explains the basic assumption upon which each mode is grounded (Table 1).

Table 1. The four modes of thought used to distinguish the meanings of important theoretical and practical terms.

Mode of Thought	Description	Assumption
Construction	A process by which parts are put together	Assumption of least parts, but no whole except by combination
Discrimination	A process by which arbitrary formulations are interpreted	Assumption that all distinctions are initially arbitrary
Resolution	A process by which problems are resolved	Assumption of problems and natures encountered in the middle region between least parts and a unifying ontological principle
Assimilation	A process by which englobing truths are approximated	Assumption of an ontological unifying principle, but no absolute least parts

15 *Oxford English Dictionary*, s.v, "system."

16 Richard McKeon, "Philosophic Semantics and Philosophic Inquiry," in *Selected Writings of Richard McKeon: Philosophy, Science, and Culture*, vol. 1, ed. Zahava K. McKeon and William G. Swenson (Chicago: The University of Chicago Press, 2005), 209–21; Richard McKeon, "Philosophy and Method," in *Selected Writings of Richard McKeon: Philosophy, Science, and Culture*, vol. 1, ed. Zahava K. McKeon and William G. Swenson (Chicago: The University of Chicago Press, 2005), 183–208; Richard McKeon, "Philosophy and Action," in *Selected Writings of Richard McKeon: Philosophy, Science, and Culture*, vol. 1, ed. Zahava K. McKeon and William G. Swenson (Chicago: The University of Chicago Press, 2005), 406–28.

Though McKeon addressed problems in a wide variety of disciplines over the course of a long career, his work in the period of 1968 to 1972 has special significance for design. In essays such as "The Uses of Rhetoric in a Technological Age: Architectonic Productive Arts," "The Philosophy of Communications and the Arts," and "Fact and Value in the Philosophy of Culture," McKeon lays the foundations of a humanistic approach to communications and construction that has continuing importance for the development of theory and practice in design.[17] It presents a sharp contrast with Herbert Simon's 1968 *The Sciences of the Artificial* and his vision of a neo-positivist science of design. The period from 1968 to 1972 has greater significance for design than is generally recognized, extending today in the difference between artificial intelligence (AI) and the human control of AI through the concepts of intelligence amplification (IA).[18] The Chicago nexus of design thought that emerged in the period of 1968 to 1972, linking Dewey (who taught at Chicago and influenced the university), Moholy-Nagy (a friend of Dewey, influencing the New Bauhaus in Chicago), Simon (a student of the neo-positivist Rudolf Carnap at Chicago), and McKeon (Dean and Professor at Chicago and a student of Dewey and F. J. E. Woodbridge at Columbia, and Étienne Gilson in Paris) deserves close attention if one is to understand the humanistic turn in design theory and practice. It also helps to explain the difference between the unfolding of a humanistic philosophy of design and the neo-positivist design philosophy of Simon and others, and, further, the emergence of rhetoric and dialectic in design in the following decades.

The four modes of thought are evident in the four broad clusters of definitions of system in common usage (Figure 2). The first cluster of definitions is quite familiar: A system is an ARRANGEMENT of interacting parts or bodies combined under the influence of related forces. Sometimes *assembly* is substituted for arrangement but the shared meaning is evident. The key term often appears in discussions of one or another of the sciences, such as physics or chemistry. But it may occur in discussions of other phenomena such as the social sciences or economics. The parts tend to be physical or material objects and the forces that influence the parts are typically regarded as natural, though often with the added forces of convention, human behavior, law and custom which are also significant. Systems from this perspective represent the mode of *construction*. Construction is a process by which parts are put together in an arrangement or assembly. It is based, as McKeon describes, on the assumption of least parts and the idea that there is no whole except by a combination of the parts under the influence of external forces.

In contrast, the second cluster of definitions is perhaps less familiar but still easily recognized. A system is a SET of units, parts, or members arranged and related to form a unity. This term is perhaps familiar from the study of mathematics, where it is found in set theory. There is no reference to natural forces in this definition, because in a significant sense the set is arbitrary, depending on the intent of the agent who specifies the set. For example, "Let X be the set of all positive integers." The set is determined by human agency, and selected to meet a human intent or purpose in the interpretation of phenomena. Whether the set is established in mathematics or in any other area of human experience, the unity of the set is the unity specified by the agent and his or her formulation of an environment of experience, not by nature or some other organizing principle. Systems from this perspective represent the mode of *discrimination*. The system is arbitrary, and the assumption is that all distinctions are, as McKeon describes, initially arbitrary.

Another cluster of definitions is more familiar. A system is a GROUP of units or elements forming a whole and operating in unison to accomplish some function or purpose. The term suggests an organic, living relationship. It is natural in one sense, but the metaphor of a natural living relationship extends into social groups: a family, a community, a political interest group. The units or elements are

17 Richard McKeon, "The Uses of Rhetoric in a Technological Age: Architectonic Productive Arts," in *Selected Writings of Richard McKeon: Philosophy, Science, and Culture*, vol. 2, ed. Zahava K. McKeon and William G. Swenson (Chicago: The University of Chicago Press, 2005), 197–216; Richard McKeon, "Philosophy of Communications and the Arts," in *Selected Writings of Richard McKeon: Philosophy, Science, and Culture*, vol. 2, ed. Zahava K. McKeon and William G. Swenson (Chicago: The University of Chicago Press, 2005), 307–26; Richard McKeon, "Fact and Value in the Philosophy of Culture," in *Selected Writings of Richard McKeon: Philosophy, Science, and Culture*, vol. 1, ed. Zahava K. McKeon and William G. Swenson (Chicago: The University of Chicago Press, 2005), 429–35.

18 The term "IA" emerged in the 1950s in the work of various writers and researchers in computer science. Generally, Intelligence Amplification (IA) refers to the effective use of information technology to augment, extend, or enhance human intelligence. According to Wikipedia, "it has a long history of success, since all forms of information technology, from the abacus to writing and the Internet, have been developed basically to extend the information processing capabilities of the human mind." Those capabilities have not yet received deep systematic attention from the design community, where work tends to be limited to various forms of bio-prosthetics. But in the face of the increasing influence of AI in daily life, one may anticipate that designers and design theorists will give more attention to human intellectual capabilities and IA. Wikipedia, s.v. "Intelligence amplification," last modified May 1, 2019, 00:14, https://en.wikipedia.org/wiki/Intelligence_amplification; see also Alvin DMello, "Rise of the Humans: Intelligence Amplification Will Make Us as Smart as the Machines," *The Conversation*, October 15, 2015, http://theconversation.com/rise-of-the-humans-intelligence-amplification-will-make-us-as-smart-as-the-machines-44767.

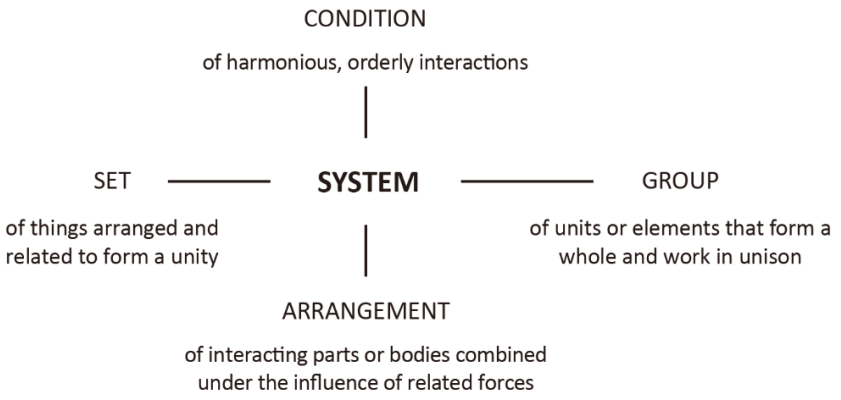

Figure 2 Definitions of system. Copyright © 2019 Richard Buchanan.

not necessarily physical or material in the sense of an arrangement or assembly. Rather, they are the functional units or elements relevant to the phenomena under consideration, such as the organs of the body. The term is easily applied to the arts and design. A company of players performs a drama; the company forms a group, united in a dramatic performance. Aristotle identifies the elements of drama as action, character, thought, diction, melody and spectacle, united together in a plot that accomplishes an aesthetic and moral goal. The "plot" *is* the system, and it is a group of functioning elements. In design, the elements of products are often identified as the manner or technology of production, the materials, and the form and function to be performed. Systems from this perspective represent the mode of *resolution*. The identification of a system comes from recognition of a problem in a body of phenomena and a process of resolving the problem through analysis and synthesis. Instead of assuming least parts (entities such as atomic or material parts that cannot be further reduced) or the arbitrariness of a formulation and its interpretation or even an englobing principle that transcends phenomena, this mode assumes that there are problems and natures in our environment that can be addressed systematically in research, action, or creation. The parts are identified by their relevance to the object of thought under consideration. The system may be analyzed into its constituent elements for study and then the elements may be synthesized through logic, art, or design into a new system that serves a new or refined purpose.

The last cluster of definitions – a small but significant cluster – is perhaps the most puzzling at first glance, particularly for those who define a system as an arrangement of parts working under the influence of external forces. A system is a CONDITION of harmonious, orderly interaction. The emphasis here is on the condition, the central property of the whole. There is no mention of parts or elements in this definition because parts are not regarded as the distinguishing feature of a system. Rather, the distinguishing feature of the system is the source of order and harmony, a source that transcends the individual parts. The parts may be of any sort – material and physical or otherwise – and the parts may be without limit in scale: there are no absolute least parts to which the system may be reduced. Instead, the system brings parts of any kind or scale into an orderly and harmonious whole based on a transcendent reason, idea, or principle. Systems from this perspective represent the mode of Assimilation. Assimilation is a process of approximating the truths or principles that organize phenomena. It is based on the assumption that there are no least parts and that there is an ontological unifying principle. Indeed, the system may be self-organizing in the face of external forces, with the logic or rationality of the whole transcending the necessities and conflicts of external forces.

Systems and the Objects of Thought

While the common definition of system is highly ambiguous, the alternative proper definitions point toward different *objects of thought and analysis*: they represent different hypotheses or ideas about the nature of the system under consideration. These hypotheses may be characterized by different descriptions and assumptions.

To illustrate the relationship of systems and modes of thought and make the discussion concrete, one can consider a gathering of students in a classroom. The gathering is a system in the commonplace meaning of the term because the students share a relationship, working together toward a common goal of learning. But aside from the commonplace understanding of a system, what kind of system is the classroom gathering? From a design perspective, what is the object of thought that should be the focus of attention in design thinking? Each mode of thought provides a different object of thought. (1) The class is an *assembly*, arranged in some seating arrangement working under an administrative system of rules that reflect a variety of external forces, such as educational requirements, disciplinary pressures that control content, grading fears and expectations, and the more distant forces of economic requirements for workforce development and cultural practices and norms. (2) In contrast, the class may be a *set*, arbitrarily determined by the professor in his or her selection of a subject for study and teaching. In this case, however, after the professor's initial selection of subject, the various interests and perspectives of students further shape the set, each student with a personal and arbitrary line of experience. The lively discussion of topics in class reflects the diversity of individual perspectives on the subject under discussion, and the set becomes complex. (3) Alternatively, the class may be a *group* with social organization and roles in teaching and learning, with some students responding to questions and other students listening and reflecting on the process of education in the subject of study; the group may even break into smaller groups or teams for project work. But the group shares more than a social structure; it also shares the common discipline that is being studied, with all of the methods and techniques that belong to that discipline. (4) Finally, the class, perhaps in its best or most idealistic expression, may be a *condition* of harmonious and orderly interaction, shaped and organized by the truth under exploration in teaching and learning. In reality, of course, the condition may only be approximated. Indeed, the condition may easily decay into disorganization when there are conflicts and sharp differences of opinion and when dialogue ceases to be a productive approach to a shared understanding. The struggle of thought to achieve a shared insight may leave the class confused and uncertain—as dialogue often leaves a gathering somewhat short of the true condition of orderly inquiry. Yet, the class moves ahead in its search for the truth that it seeks about the subject under discussion. Another way of saying this is that a gathering of students in a class strives to *become* a system and only succeeds when the gathering comes to share a common idea or value and understands the significance of the idea being explored in discussion. Most of our systems in every area of life are not really systems at all but are better understood as complex situations that, like the class, are striving to become systems.

Each concept of system in this example—arrangement, set, group, or condition—leads to a different description of the classroom and the interactions of its students. Each concept leads to a different object of thought and, hence, points to different issues and questions that may guide further exploration of what it means to teach and learn. And each concept leads to different opportunities for design in shaping an educational experience, provided that the teacher or designer has the essential ingredients of design: ingenuity and imagination. In this sense, the classroom is an analogy for the work of designers as they work toward an objective in their practical engagement with issues and problems in the wider environment of design thinking.

What is the value of recognizing the ambiguity of the concept of system and reflecting on the different meanings that system can have? In part, the value lies in better understanding the diversity of systems that one may identify in design work. The object of thought and design varies with the different meanings of system. However, recognition of the ambiguity of the concept of system is also a cautionary tale for designers as they consider the value of systems thinking for their work.

Alternative Accounts of the Rise of Design and Design Thinking

There are two broad accounts of the rise of design and design thinking in the context of management, organizational development, and the complex wicked problems of the systems and environments of human experience. Systems thinkers who shaped or were educated in the traditions of general systems theory, cybernetics, and systems thinking – Kenneth Boulding, Russell Ackoff, C. West Churchman, Peter Checkland, and many others – tend to provide a similar account, based on the application of systems concepts to an exceptionally diverse range of phenomena. Their accounts are similar because they believe that a system understanding, while highly theoretical in modeling, can come to ground in specific disciplines and, most important here, in the desire for practical action. Their work is highly interdisciplinary, yet the theme of systems connects their diverse experiences. As Boulding argues in his well-known paper

> "General Systems Theory is a name which has come into use to describe a level of theoretical model-building which lies somewhere between the highly generalized constructions of pure mathematics and the specific theories of specialized disciplines."[19]

His focus is on establishing a new science of systems. From a similarly elevated perspective, Russell Ackoff explains, "System is more than just a concept. It is an intellectual way of life, a worldview, a concept of the nature of reality and how to investigate it – a *Weltanschauung*."[20] His work sought to embed systems thinking inside his vision of design thinking; his concept of idealized design was presented in the venue and typically enthusiastic style of a management consultant. "Idealized design is a way of thinking about change that is deceptively simple to state: In solving problems of virtually any kind, the way to get the best outcome is to imagine what the ideal solution would be and then work backward to where you are today."[21] Ackoff then outlines what he regards as the steps of idealized design that can be applied to organizations in order to effect change – steps that most designers would regard as rather commonplace.

Other writers provide similar accounts, identifying what they regard as important features of moving from abstract systems concepts to practical action, always based on systems analysis of the complexity of the surroundings and environment of human experience. The particular features of design practice in these accounts vary greatly, with different versions of the steps of design process, but they are informed by what the systems theorists believe is better understanding of how complex our surroundings are – perhaps not an entirely profound observation. Curiously, however, few of the early accounts of general systems theory or systems thinking and its application to design practice include any reference to the work of professional designers and design theorists of the twentieth century. It is as if they never existed and never, themselves, held views on alternative concepts of systems.

There is no simple comparison between the specific practices of design viewed from the perspective of general systems theory and the historical and contemporary practices of professional designers working in the various design disciplines. As Peter Jones observes, there are many variations across the breadth of the design

19 Kenneth E. Boulding, "General Systems Theory—The Skeleton of Science," *Management Science* 2, no. 3 (1956): 197, available at https://www.jstor.org/stable/2627132. For an example of modeling system dynamics in the context of management, human systems, and policy design, see John D. Sterman, "System Dynamics: Systems Thinking and Modeling for a Complex World," *Working Paper Series* (ESD-WP-2003-01.13-ESD Internal Symposium), Massachusetts Institute of Technology Engineering Systems Division, Cambridge, MA, May 29–30, 2002, available at http://hdl.handle.net/1721.1/102741. This paper demonstrates a productive relationship of systems thinking and the themes of design in the area of policy design for a large corporation.

20 Russell L. Ackoff, *Ackoff's Best: His Classic Writings on Management* (New York: Wiley, 1999), 1.

21 Russell L. Ackoff et al., introduction to *Idealized Design: Creating an Organization's Future* (Upper Saddle River: Wharton School Publishing, 2006), xxxiii.

professions, making comparison a complex matter not resolved in a single study.[22] Nonetheless, Herbert Simon explored the relationship of artificial intelligence, systems, and design thoughtfully in his writings. Most prominent is his work in the 1968 book *The Sciences of the Artificial*, regarded as an important contribution to design theory. However, a later paper in 1987 suggests either a softening of his earlier position or, as some have suggested, his recognition of the limitations of his earlier views and a changing appreciation of the actual work of designers – something in the practice of design that is not easily captured in systems of artificial intelligence. In any case, the later paper presents a somewhat different perspective on design and design practice than his earlier work.[23] One may imagine that as work of the systemic design movement develops, we may see a convergence in the emerging concept of what is sometimes called fourth-order design, the design of complex environments, organizations, and systems, where other designers are also engaged.[24]

What conclusions can we draw for an understanding of design in these accounts? A student of Ackoff, systems thinker Fred Collopy writes: "Systems thinking, as written about and practiced by Russell Ackoff, C. West Churchman, Peter Checkland and others, contained within it many of the impulses that motivate the application of design ideas to strategy, organization, society, and management."[25] By Collopy's account, design thinking in its larger scale of application to problems in management, organizations, and social life is regarded as a method comprised of many particular techniques already implicit in systems thinking. Design thinking, from this perspective, is a consolidation of practices that have found a place in, and are now made explicit by, systems thinking.

In contrast to these accounts, designers, design historians and design theorists offer a different account of the rise of design and design thinking. They point out that the relationships among design, management, organizational development, and social innovation were central themes in design from the beginning of the twentieth century in Europe and then in the United States and other countries. Recognizing that designers should consider the importance of organizations in social and economic life, the distinguished designer George Nelson writes: "One of the most significant facts of our time is the predominance of the organization. Quite possibly it is the most significant."[26] He then discusses the close relationship between industrial design, business, and society, echoing similar discussions by Gropius, Moholy-Nagy, and most of the leading figures of design in the early and middle decades of the twentieth century. The further development of design and design thinking was a logical extension of the work of graphic, industrial, and interaction designers into the problems of creating the environments, organizations, platforms, and systems that shape human experience in the twenty-first century. It led, logically, to a new perspective on strategy, the nature and purpose of marketing, and technology in human life.[27] When design began to be applied to complex problems of human systems, technology, social life, and community, design thinking emerged not as a new method but as a new cultural and humanistic art and as a new discipline of practice within the broader field of design. It worked alongside and often integrated its work with the other design arts and disciplines that arose in the twentieth century: communication design, industrial design and product development, and interaction design. In this sense, design thinking is sometimes called the fourth great discipline of design, explored in the fourth order of design theory and practice.[28]

With these two alternative accounts in mind, it is reasonable to recognize that there are diverse philosophical assumptions among systems thinkers as well as designers. But it is also reasonable to identify what are often dominant assumptions in each community. For one community, the concept of a system is found

22 Peter H. Jones, *Design for Care: Innovating Healthcare Experience* (New York: Rosenfeld, 2013). Jones and others have begun to reach across to the other design professions for shared insights and new practice. An effort to overcome the separation between systems thinking and design began with the Design Methods Movement of the 1960s, where systems concepts and design appeared to converge, if only for a time.

23 See Herbert A. Simon, *The Sciences of the Artificial*, 3rd ed. (Cambridge, MA: MIT Press, 1996). For the later paper, see Herbert A. Simon, "Problem Forming, Problem Finding, and Problem Solving in Design," *in Design and Systems: General Applications of Methodology*, ed. Arne Collen and Wojciech W. Gasparski (New Brunswick, NJ: Transaction Publishers, 1995), 245–57. This book chapter was first presented at a conference in 1987. A careful comparison is called for in order to examine his views on design.

24 Richard Buchanan, "Surroundings and Environments in Fourth Order Design," *Design Issues*, 35, no. 1 (2019): 4–22, DOI: https://doi.org/10.1162/desi_a_00517; Tony Golsby-Smith, "Fourth Order Design: A Practical Perspective," Design Issues 12, no. 1 (1996): 5–25; John Body and Nina Terrey, Design for a Better Future: A Guide to Designing in Complex Systems (London: Routledge, 2019).

25 Fred Collopy, "Why the Failure of Systems Thinking Should Inform the Future of Design Thinking (06.07.09)," *Design Issues* 35, no. 2 (2019): 97–100, DOI: https://doi.org/10.1162/desi_a_00538. Originally published by *FastCompany* (online), June 7, 2009, https://www.fastcompany.com/1291598/lessons-learned-why-failure-systems-thinking-should-inform-future-design-thinking.

26 George Nelson, "The Designer in the Modern World," in *Problems of Design* (New York: Whitney, 1957), 76.

27 For Steve Jobs, technologies are regarded as tools to be placed in the hands of people. "Technology is nothing. What's important is that you have faith in people, that they're

in the *mode of construction* described earlier. The whole is more than the sum of its parts, but we only understand the whole through the arrangements and constructions of parts that are guided by the whole. The goal of general systems theory is a searching for insights into that broadest whole, seeking a "system of systems." As Boulding writes, "In recent years increasing need has been felt for a body of systematic theoretical constructs which will discuss the general relationships of the empirical world." Similar ideas form the basis of other approaches to systems thinking, all recognizing emergent properties that belong to the whole in itself rather than its parts.

For the other community, the community of designers and design thinkers, the concept of a system is often found in the *mode of resolution* described earlier. Systems are found in the middle range between two opposing concepts: (1) construction from least parts, and (2) a unifying ontological principle that transcends and organizes parts of any kind. Systems in the middle range of human experience are of many kinds. They are found in the forms and environments that we human beings create, dissolve, and reinvent to adapt our lives to the surroundings and historical circumstances within which we live. A system is an organic whole, a functioning relationship of elements that seeks to fulfill particular needs and aspirations, and it is apparent that the forms and wholes around us are nested in larger and larger wholes that must be understood for design to be successful.

Of course, both of these philosophies of system are periodically tested by alternative approaches. On the one hand, they are tested through emphasis on the arbitrary intent of individuals and communities, creating systems that are based on the *mode of discrimination* discussed earlier. On the other hand, they are tested through the promise of a *condition* of harmonious and orderly interaction to which we may aspire, based on the possibilities of the *mode of assimilation* described earlier; the assimilation may be an approximation in the search for an ontological unifying principle of transcendent values that may be spiritual, cultural, or intellectual. Indeed, all four modes of thought are operative in the pluralism of the human community. Together, they shape human experience and the environments of living. They also serve to identify the places of conflict between alternative principles of organization.

The Value and Limitations of Systems Thinking for Design

One of the common complaints about systems thinking is that for many systems thinkers, a system is actually a reductionist abstraction—it treats systems in an abstract modeling as the arrangement or assembly of parts, as discussed earlier. It is ironic that systems thinking, originally an effort to overcome the reductionist tendencies of materialist philosophy, simply inverted the materialist order of bottom-to-top to become top-to-bottom in order to focus on the emergent properties of a material whole. The reason for the inversion was a change of principles among investigators: a change of perspective from a principle of the parts (from which one could construct more complex phenomena) to a principle of the whole (by which to organize the parts based on properties of the constructed whole). It is a modeling of the many factors in a situation that make the situation complex and difficult to understand. However, systems thinking also tends to fail in addressing the social and environmental issues in the concrete particular circumstances of human beings. For example, the architect Alexandra Jayeun Lee, treating design as a method, writes: "The dynamic and often improvised nature of design process, and the desire for the particular, were inherently incompatible with deterministic rationality of early systems approach."[29] Referencing the perspective of Horst Rittel and Martin Webber, she goes on to write: "The main shortcoming of systems thinking is

basically good and smart, and if you give them tools, they'll do wonderful things with them." Jeff Goodell, "Steve Jobs in 1994: The Rolling Stone Interview," *Rolling Stone*, June 16, 1994, last updated January 17, 2011, https://www.rollingstone.com/culture/culture-news/steve-jobs-in-1994-the-rolling-stone-interview-231132/. Of course, other perspectives on the nature of technology have also emerged in a large, diverse literature. See Carl Mitchan, *Thinking Through Technology: The Path between Engineering and Philosophy* (Chicago: The University of Chicago Press, 1994). On new developments in marketing, see Philip Kotler, "Humanistic Marketing: Beyond the Marketing Concept," in Philosophical and Radical Thought in Marketing, ed. A. Fuat Firat, Nikhilesh Dholakia, and Richard P. Bagozzi (Lexington: Lexington Books, 1987), 271–89.

28 Buchanan, "Surroundings and Environments."

29 Lee, *Resilience by Design*, 21.

that the reductionist nature of systems fails to consider the complex social and environmental conditions in which they operate." To this view, we may also add that systems thinking sometimes fails to adequately consider the concrete experience of individuals, who live, work, play, and learn in the particular environments of their lives.

In contrast, there is a theme in the development of design from the nineteenth century to the present that is periodically expressed in the work of writers such as the nineteenth century scientist Claude Bernard, philosopher John Dewey, systems thinker Geoffrey Vickers, and many others who provide the theoretical foundations of design. Indeed, it touches down concretely in the work of most practicing designers and those who reference design thinking, emphasizing the importance of experimentation and human experience in how we shape and reshape the world around us. From this perspective, a system is not an assembly or arrangement of parts that are aggregated in a whole. Instead, a system for many designers and design theorists is better understood as an organic whole of units or elements that form a whole and function together, working in unison to accomplish a human purpose. The system is a *group*, as described earlier, rather than an assembly of parts subject to external forces.

This is evident in the work of anthropologist Bonnie Nardi and researcher Vicki O'Day, both with backgrounds in design and work in Silicon Valley. In *Information Ecologies*, Nardi and O'Day define information ecology as a system.

> "We define an information ecology to be a system of people, practices, values, and technologies in a particular local environment. In information ecologies, the spotlight is not on technology, but on human activities that are served by technology."[30]

With emphasis on the biological metaphor of ecology, Nardi and O'Day identify the elements or parts of the system as functional units, comprised of people, practices, values, and technologies. In turn, they emphasize the particular local environment as the key for design. This is clearly a concept of system in the lineage of a group, discussed earlier.

> "We find the ecology metaphor powerful because it includes these local differences, while still capturing the strong interrelationships among the social, economic, and political contexts in which technology is invented and used. When autonomous technology is observed at the systemic level, its effects can seem overwhelming. But in individual local settings, we see a more varied texture of experience than we see from a distant vantage point. From the local perspective, we see paths toward creating reflective and purposeful uses of technology."[31]

Writing in 1999, they point toward experimentation with participatory design in the development of software, anticipating the arrival of the Scandinavian approach in Europe and the United States.

> "In the United States, however, participatory design is still primarily an experimental approach of researchers in universities or industrial research labs. It is not practiced in product settings where the goal is to develop widely used, shrink-wrapped software, for example. Ironically, product developers fear that collaborating with users in a few particular settings would make their software less generally usable by all – perhaps it is better to work closely with *no* users, so everyone will be at an equal disadvantage."[32]

For Claude Bernard, writing in the 19th century, the theme took shape in the importance of experimentation grounded in experience. In a passage that is

30 Bonnie A. Nardi and Vicki L. O'Day, *Information Ecologies: Using Technology with Heart* (Cambridge, MA: MIT Press, 1999), 49.

31 Ibid., 47.

32 Ibid., 44.

cautionary about the aspirations of the human mind, he writes: "The nature of man is metaphysical and proud."[33] He goes on to observe that human beings have come to think that the idealistic creations of the mind also represent reality: the human being "does not contain within himself the knowledge and criterion of external things, and he understands that to find truth he must … submit his ideas, if not his reason, to experience." This is a useful observation when reflecting on systems thinking, because what we often regard as systems are actually models of systems rather than the reality of the phenomena that we would like to think of as systemic. A similar distinction lies behind the observations of Geoffrey Vickers in his article on systems analysis, "The Poverty of Problem Solving."[34] In this article, Vickers turns from the general theory of systems to the work of systems analysis. Systems analysis is the operational aspect of systems thinking that is of practical interest and value to designers. Systems analysis, Vickers argues, is a means of understanding complex situations; it is a way of interpreting the complexities of a situation, revealing the many factors and interdependencies that exist. In this sense, systems thinking and systems analysis is a valuable method for providing insight into the context that surrounds the work of design.

Vickers argues that what systems analysis does not reveal are the problems that could or should be addressed by human action to change complex situations. This is what Vickers means by the poverty of problem solving. Problem solving is impoverished by overconfidence in the contribution of systems thinking and systems analysis. The limitation of systems thinking for design is the mistaken belief that once we have found what we believe to be the factors that create the complexity of a situation (and may lead to undesirable outcomes in life), we then can rationally identify the problems to be addressed. For the richness of problem solving, he turns to human experience and the identification of problems found in concrete experience in local circumstances.

For John Dewey, the focus on experience was a recognition that our knowledge of the world is no longer gained by nature, but by art.[35] For Dewey, that art is the art of experimentation, grounded in human experience. Experimentation, of course, was central in the Gropius vision of the Bauhaus, where it was the hallmark of research and practice. This is a theme that tempers systems thinking, turning from analysis to the disciplines of synthesis and the making of the environments that surround us in our lives. Design is the discipline that transforms surrounding into environments, often through "small wins" in the effort to design better systems and environments that designers may imagine and realize with creative focus.[36] Small wins is the theme of an article by Karl Weick, the organizational theorist who has written on the problems of organizational culture, the work of redesigning organizations, the importance of sensemaking, problem definition, and other concepts relevant to our concern for systems thinking. He writes: "The massive scale on which social problems are conceived often precludes innovative action because the limits of bounded rationality are exceeded.… People often define social problems in ways that overwhelm their ability to do anything about them."[37] He proposes what designers have known from an early time: focusing on small wins is a way to address changes in our surroundings that otherwise seem impossible in social life.

This leads to a provocative question for systems thinking: Do human beings ever really experience a system? There are two answers to this question. From one perspective, it is clearly – and virtually by definition – impossible to experience a system if what we mean by system is a model of the complexity of a situation – a model that describes the past, present, and future of a situation or environment. In such a case, the understanding of a model is not the same as experiencing the reality of a complex situation. As it is often said, "the map is not the territory."

33 Claude Bernard, *An Introduction to the Study of Experimental Medicine* (New York: Dover, 1957). Bernard is often regarded as one of the greatest scientists of the past two centuries. His research helped to establish the foundations of modern medicine, and his discussion of the nature of science and scientific reasoning continues to have value. See John G. Simmons, *Doctors and Discoveries: Lives that Created Today's Medicine* (Boston: Houghton Mifflin Harcourt, 2000), 17.

34 Geoffrey Vickers, "The Poverty of Problem Solving," in *Systems Analysis in Urban Policy-Making and Planning*, NATO Conference Series, vol. 12, ed. Michael Batty and Bruce Hutchinson (Boston: Springer, 1983), 17–28, DOI: https://doi.org/10.1007/978-1-4613-3560-3_3.

35 John Dewey, "By Nature and By Art," *Philosophy of Education* (Problems of Men) (1946; Totowa: Littlefield, Adams, 1958). It is no surprise that Dewey's work, such as Art as Experience, continues to influence design and design thinking. For a comparison of the work of Dewey and Simon, see Richard Buchanan, "Thinking about Design: An Historical Perspective," in *Philosophy of Technology and Engineering Sciences: Handbook of the Philosophy of Science*, ed. Anthonie Meijers (Amsterdam: Elsevier, 2009), 409–54, especially 418–26.

36 Buchanan, "Surroundings and Environments."

37 Karl E. Weick, "Small Wins: Redefining the Scale of Social Problems," *American Psychologist* 39, no. 1, (1984): 40–49, DOI: https://doi.org/10.1037/0003-066X.39.1.40; see also Karl E. Weick, "Rethinking Organizational Design," in Managing as Designing, ed. Richard J. Boland, Jr. and Fred Collopy (Stanford: Stanford University Press, 2004), 36–53.

The model points toward certain relationships in a situation, but the situation itself exceeds the ability of the model to encompass it. Indeed, if what we mean by a system is not the model but the actual totality of all that has happened, is happening, and will happen in a hypothetical system, then we must recognize that this is beyond any individual's capacity to experience. For example, one may understand the conceptual model of the Solar System, but our actual experience of the Solar System is limited to however many times we have circled the Sun in our lives. Indeed, the model of a system (including the Solar System) is under continual review and modification as we discover new factors that heretofore have not been included in the model.

This leads to the second answer. If what we experience is not the system itself, which is a fragile and abstract conceptual model, limited by the proud but frail ability of human beings to capture the actual complexity of our environment, what is it that we experience? It can only be our personal pathway through the complexity of the situation: We experience our individual pathways through what we believe may be a system, whether in actuality or in potentiality.[38] Design is concerned with human pathways. Pathways give us insight into the obstacles that we face, the problems that we encounter, and the possibilities of change and improvement. Indeed, it is important that once systems thinking and analysis has mapped the territory of a situation, systems thinking then quietly moves aside and systems thinkers turn to the practice of design to study human beings and create pathways of experience. What is often the case, however, is that systems analysts have too little recognition or practical understanding of the practices and concepts of design that enable designers to find problems, explore possible resolutions, develop prototypes of policy or law or practice, and test and evaluate the consequences. Systems analysis does its job when it reveals the interdependencies of the many factors that influence outcomes. It is a useful but not necessarily exhaustive body of contextual knowledge. And isn't this what designers have known from the beginnings of their discipline, working under such limitations?

Systems thinking reveals the complexity, interrelationships, and many of the interdependencies that exist in our surroundings. But it does not lead to action except through the agency of the discipline of design, an art of action. Design is more than the set of methods and techniques to which it is often reduced in the approaches of system thinking. Design and the thinking upon which it depends is a cultural and humanistic art, a discipline of transforming surroundings into environments for human experience. Perhaps ironically, those environments, themselves, are products that may be considered to be systems and systems within systems. Indeed, in the most complex work of design in the fourth order, designers often attempt to create systems on the scale of social, economic, and political systems, with failures but also with some successes.

The Search for Common Ground

The rise of design thinking is a common theme shared in accounts offered both by systems thinking and design, but the beginnings and endings of their accounts are quite different. Systems thinking begins with a concept of systems and ends with the need for design action. Design thinking begins with creative inquiry in action and ends with the creation of systems of diverse scales, ranging from communications and artifacts to activities and organizations. Is there a common ground between systems thinking and design thinking that involves more than a methodological rapprochement? The answer may lie in a mutual concern for the principles of action and the principles implied in the different concepts of systems and design that are held in theory and practice. In the face of new technological developments

38 Richard Buchanan, "Management and Design: Interaction Pathways in Organizational Life," in *Managing as Designing*, ed. Richard J. Boland Jr. and Fred Collopy (Stanford: Stanford Business Books, 2004), 54–64.

and newly emerging individual and social expectations, there is an opportunity to make design principles and the principles of systems explicit in a new conversation about the issues that concern us. We should discuss the reasons for the judgments that we make in designing, and discuss how design thinking may help us overcome the wicked problems found in the conflicts of ethical issues.

There is no expectation that such a discussion will lead to agreement on the principles of the world we are making. Our communities reflect an important pluralism of views that is a source of strength and ongoing creativity. However, one should remember that the rise of systems thinking was originally based on recognition of the importance of principles and, specifically, the perception and discovery of new principles in the material world – namely, the concept of wholeness that exceeds the sum of the parts. The word *system*, itself, implies *principle* in the way a system provides organization and interdependence of parts in working toward a common purpose. Hence, all of our discussions of "system," whether among system thinkers or design thinkers, find their grounding in the nature of principles. Yet in our time, with an obsession for data and facts, we find it difficult to discuss the nature of principles or even to recognize the existence and guiding operation of principles in organizing our work and our lives.[39]

When principles are mentioned, they are usually treated in vague gestures toward the purpose of design in serving human beings or, more often, in narrow rules-of-thumb recommendations about methods of practice. In whatever discussion there has been in recent years, there is little or no explanation of (1) what a principle is, (2) what role a principle plays in organizing the complexity of design practice, and (3) how a principle affects the significance of design for individuals, society, or culture. Yet, principles are both beginning points and end points of inquiry. They direct attention in perception toward issues and problems that should be addressed, the materials and component parts of a system, the order of action in a sequence of operations or system performance, and the final purpose toward which a system – that is, any human product – is oriented.[40]

There are several areas that suggest where systems thinking and design thinking could join in a conversation about principles. These areas emerge from time to time in the literature of both communities, though they are seldom treated with the attention they deserve. It is the interaction of these areas that reveals some of the most important conflicts and dilemmas of our time. They are captured in the dilemmas and discussions of the good, just, useful, and satisfying in human experience (Figure 3).

39 The nature of principles is often discussed in the philosophical writings of Richard McKeon. For example, see McKeon, "Philosophy and Method"; Richard McKeon, "Principles and Consequences," *The Journal of Philosophy* 56, no. 9 (1959): 385–401, DOI: https://doi.org/10.2307/2022786.

40 This is the theme of a working conference, "Experience and Principles of Design," organized by the Experience Design Research Lab at Tongji University and held in Shanghai from May 16–18, 2019.

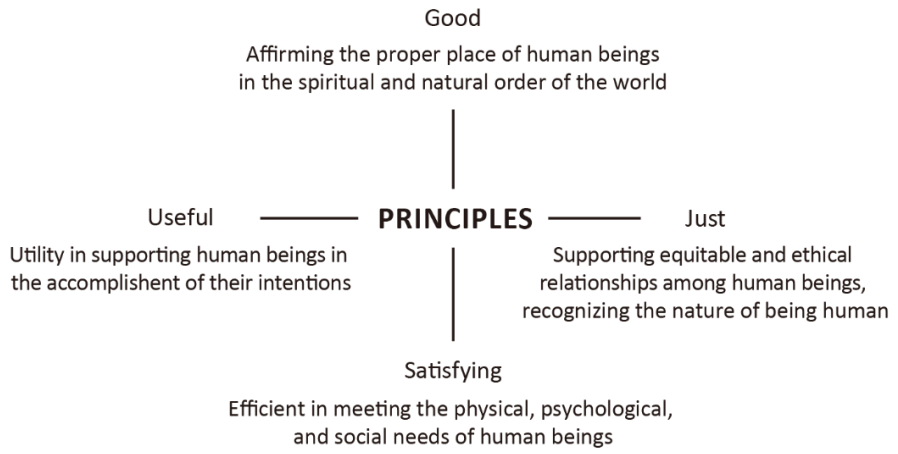

Figure 3 Diverse First Principles in Design. Copyright © 2019 Richard Buchanan.

The interaction of principles in these areas often leads to the dilemmas of issues such as privacy, comfort, sustainability, flourishing, fairness, and inequality that we find as the presenting face of troubled systems.

The neglect of principles sometimes leads to the complicity of designers and system thinkers in the failures of the large platforms – technological or social – that affect our lives. Overcoming this neglect is a challenge for which the design and systems communities may not be well prepared, since there is often too little discussion of the nature and influence of principles in making and living our lives. Yet, it is the kind of challenge to which the disciplines and our diverse philosophical beliefs can turn if we have the will and the restless imagination that characterizes creative design.

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