Systemic Design Principles for Complex Social Systems

Peter H. Jones

Abstract Systems theory and design thinking both share a common orientation to the desired outcomes of complex problems, which is to effect highly-leveraged, well-reasoned, and preferred changes in situations of concern. Systems thinking (resulting from its theoretical bias) promotes the understanding of complex problem situations independently of solutions, and demonstrates an analytical bias. Design disciplines demonstrate an action-oriented or generative bias toward creative solutions, but design often ignores deep understanding as irrelevant to future-oriented change. While many practitioners believe there to be compatibility between design and systems theory, the literature shows very few examples of their resolution in theoretical explanation or first principles. This work presents a reasoned attempt to reconcile the shared essential principles common to both fundamental systems theories and design theories, based on meta-analyses and a synthesis of shared principles. An argument developed on current and historical scholarly perspectives is illuminated by relevant complex system cases demonstrating the shared principles. While primarily oriented to complex social systems, the shared systemic design principles apply to all complex design outcomes, product and service systems, information systems, and social organizational systems.

Keywords Design theory • Framing • Service systems • Social systems • Systems theory

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Introduction

Systems theory and its guidelines in practice—systems thinking—have been promoted as the best techniques for raising social awareness about interconnected complex systems, which might determine human destiny. Societal problems have grown to levels of existential risk, and human limits to cope have been reached or breached. We find ourselves socially incapable of marshaling the political will to enact appropriate decisions and forge long-term actions resolutely addressing these problems. The systems disciplines are not to blame for the failure of social will, but the analysis processes and methods claimed as uniquely effective for these problem situations have failed to advance the human crises of climate change, energy production, political organization, connected economies, globalized corporations and labor, and urbanization. The systems movement has been critiqued as failed, solipsistic or unrealistic (Ackoff, 2004; Collopy, 2009; Jones, 2009), leading some to call for integrating systems thinking with practical methods of design practice.

For decades we have seen cycles of convergence and divergence between systems theory methods and the creative design disciplines. While some thinkers have articulated systems thinking as a design process (Ackoff, 1993) or design as a systemic discipline (Nelson, 1994), these positions are not the norm within each field. Drawing across recent literatures, very few studies have defined this emerging position. In a conference paper, Pourdehnad, Wexler, and Wilson (2011) present a recent approach to define a consensus integration of system thinking and design thinking, as a strong systemic view of complex system problems addressable by the intuitive and abductive approaches implicit in design thinking. From a design science tradition, Baskerville, Pries-Heje, and Venable (2009) proposed an integrated view of generic design process with a soft systems/action perspective. Most of these ideas recognize the perspective of design as a practical problem solving epistemology, one that may be considered third culture with science and arts/humanities (Cross, 1990). This idea is supported by the increasingly-popular belief that "all people are designers," at least in the sense of people intentionally constructing their work and lives.

The first conceptual blending of design and systems thinking formed with design science, a systematic approach to defining large-scale systems. The development of design science attempted to bridge design practice and the empirical sciences, following Fuller (1981) and Simon's (1969) positions of design as a process of creating sophisticated forms and concepts consistent with scientific and engineering principles. In practice, design science evolved toward a strong orientation to design methods and process, manifesting a systematic mindset and approach, but without the creative discovery of science or design. The inherent rationalism of design science and the first design methods movement were later rejected by even some of the originating designers and theorists. As Cross (2001) explained:

> So we might conclude that design science refers to an explicitly organised, rational and wholly systematic approach to design; not just the utilisation of scientific knowledge of

artefacts, but design in some sense a scientific activity itself. This is certainly a controversial concept, challenged by many designers and design theorists.

New transdisciplinary applications of design science may be migrating toward the systemic design approach. Upward's (2013) strongly sustainable business model research develops a design process and ecological systems theory as a methodology for redesigning business models toward sustainability goals. With an evaluation model based partially on Baskerville et al. (2009) design science method, Upward's systemic design process formulates the sustainable business model not as an abstraction but as a social, ecological and economic system design.

The domains of systems theory and design have enjoyed an uneasy and irregular relationship that allows each field to claim knowledge of the other. Practitioners in both domains have attempted to entail the more effective models and techniques from the other field, but usually in piecemeal fashion, and only if a problem was so suited. Two contemporary examples include the principles of biomimicry, as developed in environmental design, and the instrumental forms of design thinking found in the professions and management.

There appears to be insufficient agreement regarding the name, scholarly positions, and curriculum in this emerging interdisciplinary field. However, the recent formulation of *systemic design* draws on the maturity of these long-held precedents toward an integrated systems-oriented design practice (Nelson & Stolterman, 2012; Sevaldson, 2011). Systemic design is distinguished from service or experience design in terms of scale, social complexity and integration. Systemic design is concerned with higher order systems that encompass multiple subsystems. By integrating systems thinking and its methods, systemic design brings human-centered design to complex, multi-stakeholder service systems as those found in industrial networks, transportation, medicine and healthcare. It adapts from known design competencies—form and process reasoning, social and generative research methods, and sketching and visualization practices—to describe, map, propose and reconfigure complex services and systems.

Systemic design views design as an advanced practice of rigorous research and form-giving methods, practices of critical reasoning and creative making, and of sub-disciplines and deep skillsets. As professional practices with deep specializations, industrial design, interaction design, service design, information and visual design all have relevant differential cases and unique adaptations of systems thinking. While a deconstruction of the design disciplines and their references might lead us far afield into further fragmentation, remaining in the territory of *all people are designers* leaves design practice and method as merely conceptual reasoning techniques that bestow the making rights of designers upon all problem solving roles.

Relevant principles and relationships between systems theory and design methodology are called for, independent of method. Contemporary systems theory has evolved to a stable set of preferred theories for system description (or explanation), prediction (or control), and intervention (change). Jackson (2010) mapped the predominant schools of systems thinking as hard systems, soft systems, system dynamics, emancipatory and postmodern systems thinking. Three other branches can be located in complexity science—complexity theory, network science and organizational cybernetics. The acknowledged schools do not promote a clear function of design or a relationship to design thinking. Most of them identify methods and conditions for intervention in a given system. We find no acknowledgement that the notion of "intervention" is both (a) an admission of system objectification and (b) a position on the necessity for a design process.

Systems can be described as emergent or designed networks of interconnected functions that achieve an intended outcome. Today we must conceive of all systems as social systems, or at least socially implicated systems of systems. Researchers have accepted a consensus (Stockholm Memorandum, 2011) that human intervention has intervened in all aspects of the planetary ecology, rendering even natural and ecological systems socially-influenced. The current era of time is now recognized as the Anthropocene, having passed from the relatively brief Holocene era into the human-dominated Anthropocene era in the late 1800s (Crutzen, 2002).

For the purposes of this article, a complex system refers to domains where it is nearly inconceivable that any single expert or manager can understand the entire system or operation. Typical systemic design problems are complex service systems, socially organized, large-scale, multi-organizational, with significant emergent properties, rendering it impossible to make design or management decisions based on sufficient individual knowledge. These include services and systems such as healthcare systems and disease management, mega-city urban planning and management, natural resource governance and allocation, and large enterprise strategy and operations. None of these are isolated "domains," as each of these are affected by unknowable dynamics in population and regional demographics, climate and natural ecology effects, political and regulatory influences, and technology impacts.

It is also insufficient simply to claim that these domains consist of multiple "wicked problems," which cannot be reduced and therefore must be intervened as design problems only. The complexity of such problem systems necessitates multi-reasoning and inventive methodologies well beyond the analytical systems modeling and simulation techniques preferred in system dynamics.

Systemic design is not a design discipline (e.g., graphic or industrial design) but an orientation, a next-generation practice developed by necessity to advance design practices in systemic problems. As a strong practice of design, the ultimate aim is to co-design better policies, programs and service systems. The methods and principles enabling systemic design are drawn from many schools of thought, in both systems and design thinking. The objective of the systemic design project is to affirmatively integrate systems thinking and systems methods to guide human-centered design for complex, multi-system and multi-stakeholder services and programs.

The Wickedness of Problem Systems

The concept of wicked problems (Rittel & Weber, 1973) is shared by systems and design theory, as a complex situation that cannot be reduced and analyzed with the techniques of classical problem solving and decision making. Wicked problems include most persistent social and environmental issues, such as the continuous global problems that have evolved over time. “Problems,” as we naively designate them, are essentially social agreements to name a salient concern shared within a culture. The designation of *concern* (Latour, 2008) reflects a thoughtful presentation of the social value of the meaning ascribed to problems as experienced. Latour distinguishes between *matters of fact* (problems as objectively determined) versus *matters of concern* (about which we experience care, entanglement, and share associated values with). Matters of concern are problems found relevant to the motivation for design for social betterment. Design theorists often prefer “fuzzy” or “ill-formed situation” as a rhetorical means to distanciate the social concerns embedded in the situation that could inhibit generative ideation or creative resolution. I will adhere to the common meaning of *problem* as a perceived deficiency or negative value state sufficiently significant to compel social agreement to repair or restore.

Significant societal or global problems (such as global poverty, hunger, sociopolitical violence, climate change) originally emerge from multiple root causes and become interconnected over time. As with designed systems, “problems” are situations that favor some constituents and cause unforeseen consequences to others. Problems are maintained by social agreement and tend to reinforce conditions over time, and they begin to resemble autonomous, complex adaptive systems. These co-occurring problematic manifestations can be termed problem systems. Problem systems demonstrate the whole-part identity of a system of systems, the interdependency of component systems, and the endurance of ultra-stable systems.

One of the earliest attempts to catalogue significant societal problems was the Club of Rome’s “Predicament of Mankind” project (Meadows, Meadows, Randers, & Behrens, 1972), a prospectus which invited proposals to address the most salient emerging global concerns. The Predicament was an attempt to marshal commitment across national boundaries due to the foreseeable setbacks in national political systems. The outcome of the winning proposal was the publication of “The Limits to Growth” (Meadows et al., 1972), defining the scenarios generated from the WORLD model global resources simulation. The alternative (and overlooked) proposal of Özbekhan (1970) to the Club of Rome’s project helped instantiate the social systems school of systems practice, as it was clearly distinguished as a social policy program rather than a technology-based (hard systems) simulation strategy. The rejected proposal was a design orientation to human-centered policy design and planning based on the engagement of invested stakeholders. His *problematique* was a framework for assessing the relationships among a system of closely-coupled interacting problems.

> We proceed from the belief that problems have "solutions" – although we may not necessarily discover these in the case of every problem we encounter. This peculiarity of our perception causes us to view difficulties as things that are clearly defined and discrete in themselves (1970, p. 6).

Özbekhan defined the global problematique as characterized by 49 critical continuous problems (CCPs). While these problems have been re-presented and reformulated since then (cf. Christakis & Bausch, 2006), agreement remains that these 49 remain as persistent, interconnected, and generally worsening challenges to all human societies.

The problematique was adopted by Warfield (1999) in the development of generic design science as a collective approach to address complexity surpassing individual comprehension. More recently the international Millennium Project identified 15 global challenges (Cisneros, Hisijara, & Bausch, 2013; Glenn, Olsen, & Florescu, 2012) that suggest the evolution of Özbekhan's 49 CCPs had indeed resulted in an identifiable number of significantly overlapping and interconnected global problem systems.

True wicked problems such as the 49 CCPs demonstrate changes over time, resulting in differences among problem stakeholders over the most critical issues and the definition, boundaries or problem framing. Dedicated societal and policy action toward progress on these problems inevitably reaches points of conflicting policy priorities and impasses. Original causal influences (such as bad regulatory decisions or perverse economic incentives) evolve into new effects (corrupt agencies and financial capture of regulatory regimes). Interventions have no testable solution (how would you know you have resolved the situation?) and the very acknowledgement of a "problem" results from the earlier effects of embedded, interconnected, "complicated" problems.

Problems Exist in Language

The language of design and systems differentiates with respect to the preferred actions to make progress toward the problematic situation. It is incorrect to speak of *solving* wicked problems, as there are no agreed or effective evaluation measures that would justify the claim. The idea of *dissolving* wicked problems by design thinking has a popular resonance, but little empirical meaning. According to social systems theorists, the so-called wicked problem does not exist in the world as an object or organization with definable boundaries. Warfield (2001) asserted that all problems we define, as human constructs, can be described as problem sets, with each distinct *problem* merely a component of a set or problem system.

Warfield (2001) stated that all complexity exists in the minds of perceivers, not in the system believed to be the subject of description. The frustration that occurs when observers find themselves unable to define and understand a situation leads to the explanation that the *system* is inherently complex. Stakeholders are unable to recognize that their own cognitive limitations explain the majority of the complexity. Also, most socially complex problem constructions are likely to contain *objectively complex* subsystems, or a complex of multiple relationships and feedback interactions that require significant analysis and domain expertise to unravel. Likewise, in any problem definition stakeholders underconceptualize the dimensions and factors of the field of interaction and therefore the field of designable options (or possibilities for innovation).

While this feature of complexity has been considered an argument for systems thinking, the necessity for variety and multiple reasoning pathways strengthens the argument for a strong design approach instead. Warfield's axiom, taken seriously, reveals the flaws of a hard systems analysis for optimization and problem definition. Design, or effective intervention, in complex systems requires deliberate variety enhancement and refraining from early closure. Universal design methods include reframing (boundary setting), iteration (trial-and-error of design options) and critical feedback (multiple modes of evaluation). System designers identify and reconfigure boundaries as ways of sensemaking with others, to evaluate design strategies, and to produce descriptive scenarios.

Wicked problems are predicated on the notion of *irresolvable* complexity, impossible to mitigate through analysis or the application of processes. The emergence of perceived complexity unfolds as observers investigate, learn and understand the relationships of constituent systems in the problem. Problems are considered *wicked* once understood in their ecology of relationships.

Rittel's ten distinctions of a wicked problem (Rittel & Weber, 1973) disorient any conventional view of the effectiveness of problem solving. Adapted for the purposes of this article, these are simply:

1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no stopping rules (How do we know when design is enough?).
3. Solutions to wicked problems are not true-or-false, but better or worse.
4. There is no immediate or ultimate test of a solution.
5. Every solution to a wicked problem is a one-shot trial. Every attempt counts significantly.
6. You cannot identify a finite set of potential solutions.
7. Every wicked problem is essentially unique.
8. Each can be considered to be a symptom of another problem.
9. The discrepancies (and causes themselves) can be explained in numerous ways.
10. The planner has no right to be wrong.

Problems, as phenomena, only "exist" when declared by social agreement. Yet every stakeholder or participant in a situation will be primarily concerned with dynamics that occur within the problem system perceived as significant to their interests or values. This differentiation of care results in agreements not based on common understanding of the social system, but on individual concerns for possible outcomes and opportunities understood as individually meaningful. Different stakeholders will find salience in aspects of the situation they care about, which are compelling to their experience, giving them an actual stake in the problem, a motive for taking action. Social methods are necessary for enabling people to discover experienced phenomena and to reach understanding, if not consensus, about possible paths of action. Social methods are not necessarily democratic by design, but must be to facilitate substantive and invested participation from the range of stakeholders in a problem system. Finally, social methods are necessarily processes of design, not only ideation and deliberation. The most efficacious courses of action in a complex social system are not determined analytically, or by consensus of a group, but through the interactive co-creation and assessment of proposals that synthesize a whole intervention or actionable strategy.

Design Strategies for Complex Social Systems

Design practitioners have been drawn toward design thinking as a way of formulating proposals for change and creative outcomes as the complexity of those problems considered amenable to design has increased. Recent observers often consider design thinking a contemporary development. Some consider it a discipline with insufficient maturity, literature, and precedents upon which to formulate research. Due diligence will find little agreement for a preferred definition of design thinking from the scholarly literature. References to Simon (1969) reveal a misunderstanding that the rigorous rationalism of systems theory and engineering contribute a benchmark definition upon which design thinking is based. Yet contemporary design thinking shares little in common with Simon's epistemology or methods. Perhaps the strongest claim for the term and the most pertinent approach to design is that of Buchanan (1992), whose article was first presented as a 1990 lecture on changing orders of design practice according to different formulations of problem solving, including "systemic integration."

> In this sense, design is emerging as a new discipline of practical reasoning and argumentation, directed by individual designers toward one or another of its major thematic variations in the 20th century: design as communication, construction, strategic planning, or systemic integration (Buchanan, 1992, pp. 19–20).

Systems Influences on Design Methods

The history of design methods reveals the characteristics of design thinking expressed in the methodological perspectives of their time. Bousbaci (2008) depicted the generally acknowledged three generations of design methods, with each identifying the paradigmatic shifts in prevailing design theory that followed the systems theory principles in force during those times. Table 1 illustrates a summary of his analysis supported by the author's examples of influences and outcomes, and the addition of the fourth (generative) generation.

Table 1 Four generations of design methods

Generation	First	Second	Third	Fourth
Orientation	Rational 1960s	Pragmatic 1970s	Phenomenological 1980s	Generative 2000s
Methods	Movement from craft to standardized methods	Instrumentality Methods customized to context	Design research and stakeholder methods Design cognition	Generative, empathic and transdisciplinary
Authors and trends	Simon, Fuller Design science Planning	Rittel, Jones Wicked problems Evolution	Archer, Norman User-centered design Participatory design	Dubberly, Sanders Generative design Service design
Systems influences	Sciences Systems engineering	Natural systems Hard systems	System dynamics Social systems Soft systems	Complexity

Concurrent in history to the three generations of design methods we also find three theoretical streams of design philosophy, whose underlying intellectual frameworks share significant influences among systems theorists. These philosophies (epistemological stances) can be characterized as rational, pragmatic, and phenomenological. These philosophical influences have blended with each other over the years, so that their unique contributions are deeply embedded in design thinking. The emerging consensus on design thinking represents a fourth generation of design methods, based on generative epistemology and approaches (Sanders & van Stappers, 2013).

As other stances have emerged to enrich design research (e.g., constructivist, reflective, interpretive, emancipatory) relevant methods have emerged (e.g., activity analysis, hermeneutics, participatory design). These emerging positions have been quickly translated into methodology and practice. In design practice, and often as well in design research, the links back to the scholarship are often missing. The current project of design principles attempts to link generative design guidelines to systems theoretical principles.

Social system design largely consists of models of collective inquiry for engaging stakeholders in the many different activities of designing. As acknowledged by authors Banathy (1996), Gharajedaghi (2011), and Metcalf (2010) social systems design is more a guideline for systems thinking in complex social applications. It is a multidimensional inquiry, not a "studio" practice engaged by design firms. In practice social systems are not approached with a set of design methods or a toolkit (such as IDEO's Human-Centered Design). As the social system is that which is ultimately defined by its stakeholders, the methods and strategies adopted for systemic design must be accepted and understood by these stakeholders.

Yet a cultural-historical view of design for social applications reveals a more designer-driven artifactual perspective in theory and practice. Even if systems theory and practices are not embracing the shifts in design thinking, design practices have become more systemic. However, there is a surprising paucity of literature in systems-oriented design theory and few published cases that define a systems-orientation to design.

Over the evolution of design trends, including the four generations of design methods, strategies for designing products and services within complex social systems have been advanced. These strategies include meta-design frameworks and integrated methods associated with systemic approaches.

Perhaps first among the design theorists was Richard Buchanan's (1992) definition of the orders of design (for "wicked problems in design thinking") universally applicable across design thinking. The foundational premise claimed four "orders" or design contexts that express the products of design:

1. Symbolic and visual communications
2. Artifacts and material objects
3. Activities and organized services
4. Complex systems and environments

Buchanan's observation was that designers draw upon these contexts as "placements" or ways to creatively reconfigure a design concept in a situation. Placements refer to positions employed for integrated design strategies across four classes of design targets. All designers build vocabularies of design thinking and techniques, as well as a set of skills and styles applicable in their domains of work. Designers should not follow a fixed series of orders to reach an outcome, but rather adopt placements as a strategy for creative invention.

Recognizing that contemporary designers are now involved in more complex problems and require further guidance than the doctrine of placements, van Patter (Jones & van Patter, 2009) advocates four distinct design domains. The four domains advance from simple to complex, with a series of learning and skill stages necessary for negotiating increasing complexity.

Design 1.0–4.0 stages are based on observations and necessities drawn from practice. They show different levels of understanding and skill applied to four different domains characterized by relative complexity.

The stages require an evolution of design practice, research, and education to develop new knowledge bases necessary for this increased complexity. Different skills and methods apply in each domain, that are generally transferable up, but not down the levels (Fig. 1).

The four domains embody design processes for the following contexts:

1. **Artifacts and communications**: *design as making,* or traditional design practice.
2. **Products and services**: design for *value creation* (including service design, product innovation, multichannel, and user experience), design as *integrating.*

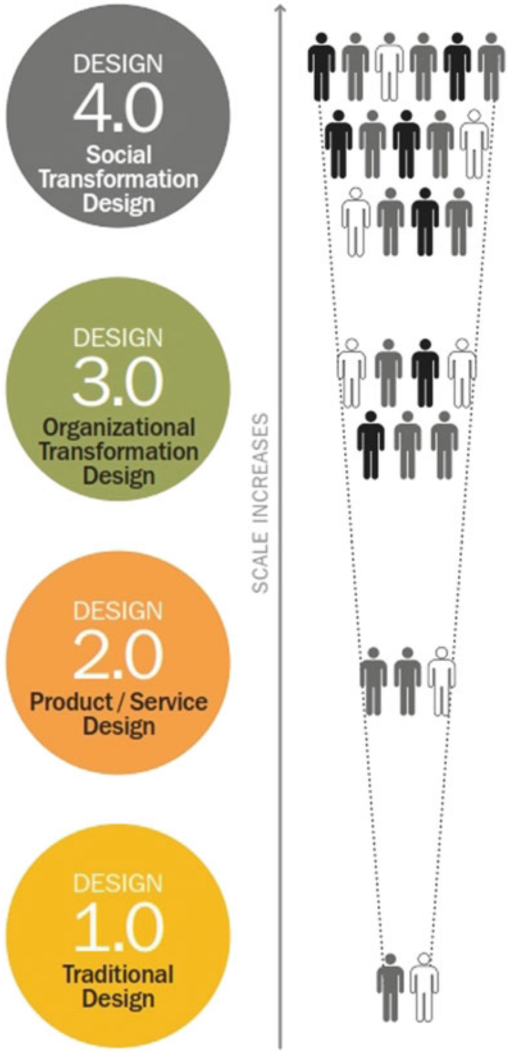

Fig. 1 Mapping design process to challenge complexity (Jones & van Patter, 2009)

3. **Organizational transformation** (complex, bounded by business or strategy): change-oriented, design of work practices, strategies, and organizational structures.
4. **Social transformation** (complex, unbounded): design for complex societal situations, social systems, policy-making, and community design.

Because of the magnitude of complexity difference in each level or stage, the stages are not interchangeable. In any given design process, the skills and orientations from *all* levels might be employed. Each higher stage is inclusive of the lower levels as the problem complexity expands from Design 1.0–4.0. An organizational process design (3.0) should present communications with the quality of the best

D1.0 work, and its process would normally be designed following the methods and practices of a D2.0 service.

The four domains differ in their strategy, intention, and outcomes. Each domain requires skill and coordination of distinct methods, design practices, collaboration skills, and stakeholder participation. These are not fixed requirements but merely entry criteria for skillful performance sufficient to meet the demands of that domain's complexity (or variety) in practice.

The relationship of these design strategies to systems practice has not been fully realized, but there are several essential influences. Each design stage reflects a distinct system boundary. The differences between a simple design project (1.0) and a market-facing product or service (2.0) are significant, and well-understood. The social complexity of an organizational boundary (Design 3.0) involves governance, operations, product line and service strategies, human resources, and all internal systems. The design context for the 3.0, complex system, requires different mindsets, value propositions, disciplinary composition, and skills. The boundary and the social system are further expanded with Design 4.0 problems of societal transformation (which includes policy design, a domain which has not generally evolved to advanced design and normative planning).

Systemic Design of Sociotechnical Systems

The four domains of design are highly interconnected in practice. A service process (Design 2.0) will necessarily require reciprocal organizational changes from its host company (3.0), and will require continual communications and enhancements designed as traditional (1.0) services. A multidisciplinary design project will coordinate appropriate designing skills relevant to the desired outcomes. However, complex social systems require significantly more dedication to social and user research than commercial products or single-vendor services. A systemic design approach integrates skills and domain knowledge across the social-organization-service levels and defines new artifacts (for example, integrated products and services) that adapt to the market (social) ecosystem and organization.

Sociotechnical systems recognizes the interdependent organization of work practices, roles, tools and technology. Fox (1995) states the goal of a sociotechnical system design is to integrate "the social requirements of people doing the work with the technical requirements needed to keep the work systems viable with regard to their environments." For services defined by their complex work, such as healthcare clinical practice, the sociotechnical systems view reveals a whole-system ecology that becomes the target of design. Figure 2 represents four layers of practices identified in the whole-system ecology of services. Each level constrains the social and work practices in the adjacent lower level within a range circumscribed by economics, practice, and professional norms. The Industry and Organization layers establish the long-term contexts, practices, roles and skills in which healthcare (or other work) is performed. Organizational change, considered a Design 3.0 problem, is

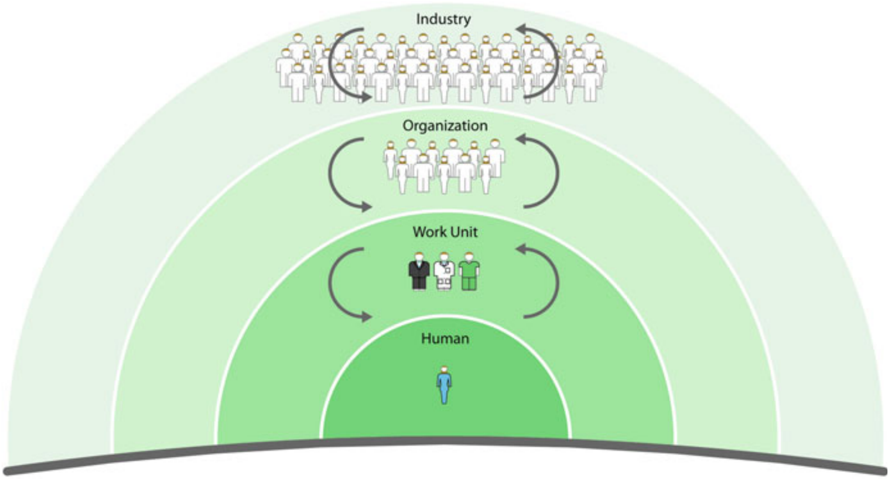

Fig. 2 Domains of social practices in a human-centered sociotechnical system

inherently limited to the historical constraints of industry and healthcare policy (both Design 4.0 concerns). Design options available to the Work Unit (Activity layer) are invisibly but powerfully determined by higher-level sociotechnical contexts.

The human in the system's center represents the conventional actor toward which technological interaction is applied—the "user," the "patient," or a "customer." The apparent isolation of the actor within the sociotechnical system model suggests that a given individual may be acted upon within the aggregate contexts of these nested social systems. The possible ranges of interaction and breakdown that may occur with the individual actor are too complex to account for. The human actor is inserted as a reminder that the purported rationale for the provision of service is to fulfill demands or needs of the given individual. In reality, service systems are designed for objectives of the highest-level contexts that supervise the process. Electronic health records systems are not procured for patient needs, or to enhance the work practices of a given activity. They primarily meet organizational objectives for reporting, information control, and operational economics. In the US, these systems have been encouraged by extraordinary financial incentives established by government policy (Industry layer), which essentially drive their procurement and deployment.

While there four layers in this model of a human-centered sociotechnical system, these layers are not isomorphic to the Design 1.0–4.0 domains. These four layers reflect a wide variety of systems and activities animated by ongoing socio-cultural practices in the world. The boundaries have well-defined meanings however, and there are typically distinct roles at the supervisory apex (CEO, division manager, policy maker) and at each subsequent unit of control. However, the design domains and skills and knowledge associated with D1.0–4.0 align with these unit-layers of sociotechnical analysis. Service designers provisioning at the work activity level (e.g. Emergency Room service redesign) will be forced to ignore larger systemic concerns, will be unable to acquire data at the organizational level, and will not be afforded access to the organizational system. However, organizational/enterprise design teams will have access and accountability to these activity systems within system-level boundaries. Design 3.0 teams would include or coordinate the resources and skills effective for the inclusive activities.

The sociotechnical perspective recognizes that real world organizations and practices are complex and messy, and technologies are appropriated into everyday work practices more than they are "integrated" in a rationalist, technology-centric approach. Rather than a formalized integrated "system" of systems, tools and socialized knowledge practices, we start to see organizations as aggregations of purposeful but historically-influenced, overlapping cultural and social systems distributed under common identities. Most of the practices we refer to as systems are merely representations; abstractions of abstractions referring to a culturally-constructed social reality.

Systemic Design Principles

Design principles provide theoretically-sound guidance for social and complex systems design. Design principles offer guidelines and a foundation for practitioners to enhance engagement and evolve better practices. Principles are elicited from systems theoretic concepts, yet do not propose any new theory. They provide elements for practitioners to form net new frameworks enabling integration of other concepts for specific design contexts.

What relationships between systems thinking and design thinking will improve design practice? How we might establish a set of principles to enable new forms of design, planning, and deliberative conversation for coordinated action? While design thinking has been developed toward business innovation and tangible design outcomes such as industrial products and branded services, the approach has more recently been adopted as a methodology for social systems change (Brown, 2009a, b; Brown & Wyatt, 2010). Design thinking has been recently promoted widely as a methodology for action in complex situations previously considered the domain of policy planning and systems engineering.

Nelson and Stolterman (2012) support the basis for design as systems thinking by integrating principles of both systems *sciences* and the systems *approach* as reasoning and thinking techniques for adapting design to complex whole system problems.

> Every design is either an element of a system or a system itself and is part of ensuing causal entanglements (Nelson & Stolterman, 2012).

We require a broad crossover of principles between systems and design theory for the purposes of expanding design practice to higher levels of complexity (Design 3.0 and 4.0). Such a fusion of design and systems thinking does not follow based on the principles held in current agreement within each school of thought. Systems and design theories and practices differ substantively, on basic principles of approach and action, and certainly stylistically. While both schools of thought and practice share appreciation for some common intellectual influences, their approaches to inquiry, research, method, action, and outcome significantly diverge. Because the two fields approach the definition of problems and the pursuit of problem solving in almost incompatible ways, the relationships between systems and design "thinking" ought not to be taken for granted.

The primary aim the two systems of thought share today is enabling appropriate, organized high-leverage action in the increasingly complex and systemic problems as *design situations*. Due to their purported efficacy in formulating action for systemic change, the tendency of theorists, if not practitioners, is to integrate the more sympathetic methods and underlying epistemologies between the two systems. As there may be several ways to elaborate such a fusion, systems designers and researchers might articulate the pivotal relationships between these schools of thought.

Systems and design thinking are both systems of organized cognitive models developed to enable practitioners to perform different types of problem solving for complex situations. The two orientations have very different approaches to formulating the "problems" of design and inquiry. Until these fundamental differences are renegotiated, their comprehensive systems of thought may be treated by designers as compatible or even similar, but their superficial relationships and shared methodologies should not be taken as evidence of meaningful integration or even compatibility.

The following section proposes an essential, yet incomplete, set of design and systems principles synthesized to examine their correspondences. These systemic design principles were drawn from the generalization of systems principles applicable to design, and design principles developed as guidelines from systems theory. A particular subset of systems-oriented design thinkers (Alexander, 2004; Dubberly, 2008; Krippendorf, 1996; Nelson & Stolterman, 2012; Sevaldson, 2011) and design-oriented systems scientists (Ackoff, 1993; Banathy, 1996; Christakis & Bausch, 2006; Ostrom, 1985; Ostrom, 2009; Warfield, 1990; Winograd & Flores, 1986) significantly influenced these selections and formulations of principles.

Shared Systemic Design Principles

A core set of systemic design principles shared between design and systems disciplines is proposed. The following are based on meta-analysis of concepts selected from system sciences and design theory sources. Design principles were selected that afford significant power in both design and systems applications, and are sufficiently mature and supported by precedent to be adapted without risk.

1. Idealization
2. Appreciating complexity
3. Purpose finding
4. Boundary framing
5. Requisite variety
6. Feedback coordination
7. System ordering
8. Generative emergence
9. Continuous adaptation
10. Self-organizing

While these principles may appear to assume universality across literatures, the intent is for applicability and adaptability of principles, not a fundamental baseline.

Process Model for Design Principles

Initial assessment of the design principles may be done by testing their fit across the phases of a design process, in abstract, and to a range of projects, to identify contributions and gaps within case studies. Nearly any well-established design process model would serve for the purposes of testing principles.

van Patter, Pastor and the OPEN Innovation Consortium (2013) recently completed a catalogue mapping over 50 innovation methods, identifying for each the design functions of pattern creation and pattern optimization. Pattern creation is the essential process of collective innovation, and pattern optimization is associated with system or process improvement. Four sets of patterns were found universally applicable across process frameworks:

- Discovery and orientation
- Definition and concept formation
- Optimization and planning
- Evaluation and measurement

Figure 3 maps these four patterns of creation and optimization within a reference design process model for service system innovation (derived in part from Evenson & Dubberly, 2010).

The model is a progressive design process, an activity timeline. Each phase contributes a significant and necessary output toward the deployed service system. The five phases provide opportunities for different creative and production team members to effectively research and design a meaningful deliverable that accrues form and function decisions and reduces market and adoption uncertainty. As a general design process model, the five phases offer our analysis a richer field of possible principles than a comparable 3-phase model (such as IDEO's HCD model, for example). Three meta-phases are indicated as major processes (exploratory,

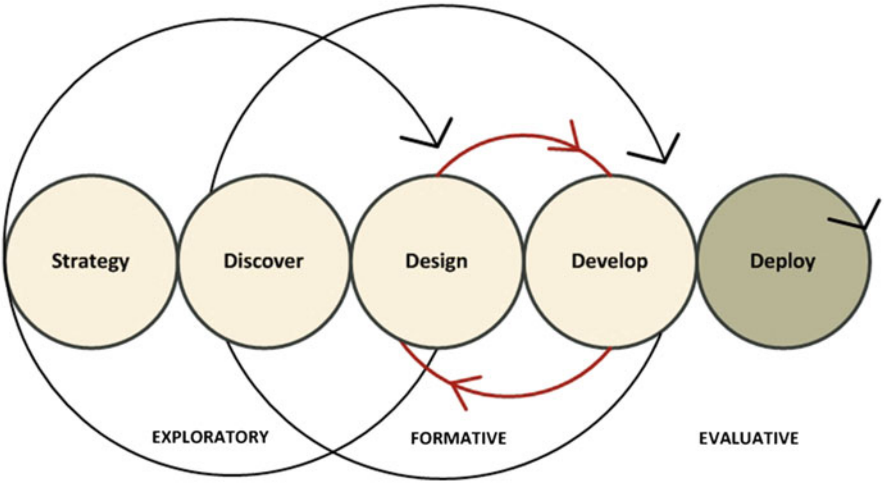

Fig. 3 Maps these four patterns of creation and optimization within a reference design process model for service system innovation (derived in part from Evenson & Dubberly, 2010)

formative, evaluative), containing variation and iteration, and as well mapping the model closely to more typical 3-phase models.

Each phase affords the resolution of one or more design principles necessary (but not fully sufficient) to fulfill the outcomes of the phase. The principles can be assessed either inductively, by testing against multiple representative scenarios, or deductively, by hypothesizing whether the principle is absolutely necessary to design success. An abductive evaluation approach is to iteratively assess the attendant risk to completion of a given design requirement if the principle remains underconceptualized.

Mapping Design Principles to Model

The ten design principles represent responses to challenges faced by most design projects, whether a commercial product, a healthcare service, or a complex social policy. If we accept the relative validity of the temporal model's orientation to processing decisions and risk from Strategy to Deployment, the design principles can be associated with risks or concerns faced by the design team (as a whole). Figure 3 illustrates the arrangement of these design principles recognized within associated phases in the conceptual design model.

Other design principles or systems axioms certainly might apply in each phase; here, only principles that *equally fulfill* design requirements and systemic relationships were selected (Fig. 4).

Different problem types will display significant variations of complexity across a given process. The proportion of effort applied to a principle's challenge will

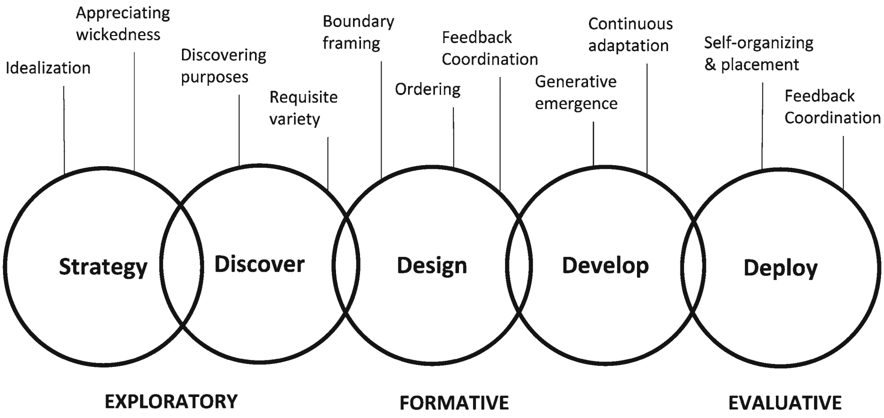

Fig. 4 Design principles mapped to design model

differ depending on whether the product is new or part of an installed platform, or the service is an integrated system or a simple service redesign. In other words, the more systemic the problem, the more critical will be the contribution of shared design principles. Design principles assume no measures of merit for their successful negotiation. But case studies drawn from actual projects will illustrate the necessity of these in each typical case.

Shared Systemic Design Principles

Further reference and definition of the design principles shows the relationship of each principle to the design and systems contexts from which they were drawn.

Idealization

Idealization is the principle of identifying an ideal state or set of conditions that compels action toward a desirable outcome, or signifies the value of a future system or practice. Idealized design (Ackoff, 1993) was codified as a systemic process for business or product strategy, developed from Russell Ackoff's insights into the organizational power of accomplishment when proposing an ideal system based on ultimate values irrespective of means.

> There is no more effective way for an organization to create its future than by continuously making its present closer to ideal. The benefits derived from idealized redesign lie not only in implementation of the plans that it leads to, but also in the learning and creativity that result from engaging in the process (Ackoff, 1993, pp. 401–402).

Idealization serves as a future-finding process. Future finding is the design function of searching for multiple alternative futures (or scenarios) consistent with a vision or intent. Strategic foresight reflects both strategic management and design practices oriented toward preferred future outcomes, as defined by Slaughter (1999).

> Strategic foresight is the ability to create and maintain a high-quality, coherent and functional forward view, and to use the insights arising in useful organisational ways. For example to detect adverse conditions, guide policy, shape strategy, and to explore new markets, products and services (p. 287).

Strategic foresight often posits idealized future scenarios as sets of options to be compared against alternative future outcomes, and develop a range of possible outcomes based on both trends studies and stakeholder engagement. Projects such as the Canadian Social Sciences and Humanities Research Council's *Imagining Canada's Future* (SSHRC-CRSH, 2013) develop both idealized strategic goals as well as a range of possible scenarios toward which planning and design might be targeted. Foresight projects tend to account for systemic changes in the search for a future ideal state.

More recently, Fry (2009) refers to design futuring as active envisioning and generative practices intended to redirect and reimagine future possibilities that lead and guide sustainability and ethical social outcomes. A classic case of an idealized design future is Buckminster Fuller's Old Man River proposal, envisioning an ideal city of 125,000 within a massive urban dome in the historically impoverished city of East St. Louis (Fuller, 1981).

Design futures are the emerging practices of formulating designed artifacts that reflect alternative future possibilities in ways that stimulate stakeholder imagination. These references reflect a definitive future orientation and even competency of envisioning, articulating, and persuasively designing for preferred human futures.

Appreciating Complexity

The principle of *appreciating complexity* acknowledges the dynamic complexity of multi-causal wicked problems and the cognitive factors involved in understanding the relationships that indicate problem complexity. The identification of wicked problems is central to the source review and a critical link between systems and design thinking. Whereas first expressed by C. West Churchman and articulated by Rittel and Weber (1973), wicked problems are distinguished from *tame* or mere simple or complicated problems by the ten factors associated with wickedness. The characteristics of multi-causal, evolving and ill-formed problems should be held to the standard of *wickedness*. Allowing any concern that has not been well-framed to be described as wicked contributes to a general diminishing of understanding.

The identity of a *problem* is essentially a frame of reference. It does not exist until it is declared, defined, and supported by argument. In design thinking it presents a lens within which a situation is recognized or declared as irresolvable by problem solving means. In design, the designation of *wickedness* is typically a shorthand reference for high complexity. Buchanan (1992) indicates wickedness as the indeterminacy that lies behind all but the most trivial design problems. Because a design solution could be one of an innumerable number of possible outcomes, the design orientation to wickedness remains flexible and intuitive, not analytic and procedural.

As noted above, Özbekhan (1970) presented a schema of 49 "Continuous Critical Problems" (CCPs) in the proposal to the Predicament of Mankind, based largely on his prior work (Özbekhan, 1968) identifying 28 such wicked problems that were increasing in complexity and "overlapping" with each other. Most of these CCPs are considered just as critical today, such as Urban and suburban sprawl, Spoilage of nature, Underemployment, Spreading social discontent, and Inadequate education. Özbekhan's insight was recognizing the nature of social complexity, where once-discrete problematic situations would converge due to overlapping root causes and become multi-causal problem systems.

Within this core principle is the problem of recognizing and declaring *requisite complexity*. Özbekhan (1969) and later studies of problematizing, such as Warfield (2001), suggest problem-finding and defining is a cognitive relationship of human perception of complexity. If a problem is recognized by both systems approach and design thinking as a cognitive percept, then a fundamental principle of *appreciating complexity* may be established. This appreciation can be recognized in the satisfaction of a design-resolution that (apparently) simplifies a complex indeterminate situation with an appropriate and salient response.

Purpose Finding

All designed products and services were implemented to serve a business or social purpose. All systems can be said to have a purpose, the abstract function that defines the whole system. The shared systemic design principle of purpose finding is not that a purpose is *identified*, but that purposes can be determined by agreement and therefore designed or redesigned.

The leverage of purposes differs across applications of the principle. Purposive systems (Banathy, 1996) are well-structured or institutionalized social systems that embed deterministic systems for a core purpose, such as a corporation or educational institution. Institutional frameworks are intended to establish purposive social systems dedicated to understood outcomes. A classical purposive social system is the hospital, which has well-defined goals and purposes built into its structure. Purposeful systems (Ackoff & Emery, 1972) are those where the same outcome of such a system can be produced in different ways, and can changes its goals, means, and ends within the system for meeting those purposes (for example, a regional transportation system).

Purpose-*seeking* systems, also called ideal seeking (Banathy, 1996), are dynamic processes of an open system seeking an ideal future state. Policies and laws are considered purpose seeking, as they are formulated based on images of the preferred future collectively shaped by society. Reform and changes to policy signal the desire to reposition society toward values consistent with the purpose being sought. Strategic foresight projects such as the SSHRC Imagining Canada's Future (SSHRC-CRSH, 2013) are also purpose-seeking in their articulation of a framework of ideals or purposes toward which future investments will be aligned. Ackoff and Emery (1972) originally defined purpose-seeking in terms of the unachievable ideals, but achievable goals:

> An ideal-seeking system is a purposeful system which, on attainment of any of its goals […] then seeks another goal […] which [it is believed] more closely approximates its ideal (Ackoff & Emery, 1972).

A startup is also a purpose-seeking entity, with an idealized product as a goal, which it is organized to achieve. Product and service design follows the purpose finding principle. Most management information systems have fixed purposes, and are designed and deployed to satisfy that purpose indefinitely. Numerous Internet services and sites may be considered purpose seeking. For example, the social media service Twitter is an open framework for posting content and following other posting authors. It has no definitive purpose, but enables its users to seek and satisfy other purposes, and may be collectively seeking an emerging purpose undetermined by the system designers.

The design guideline inherent in identifying purpose is to determine agreement on purposes, and to identify the appropriate level of purpose. Nadler and Hibino (1998) defined the Purposes Hierarchy to enable stakeholders to specify a series of purposes from "most tactical" (bottom) to highest human purpose (top of hierarchy). The purposes principle provides a whole-to-part view of the problem space, helping ensure that the right problem is being addressed. While defining purposes can lead to a more precise definition of a problem, the combination of clear purpose and creative framing resists fixation on the wrong problem or level of the problem system.

Boundary Framing

Problem framing and boundary judgments are sufficiently similar in intent and mechanics to be recognized as common principles shared between systemics and design. The aim of problem framing is to define the most effective fit between a concept and its target environment. Fit requires an iterative process of selecting boundaries and reflectively considering the associated meanings entailed by the boundary frame. For example, climate change entails an innumerable range of possible boundaries. Productive systemic design, and dialogue, requires participants to exchange their perspectives to understand the possible effects of action. Boundary frames might range from "individual behaviors" to "effects on our region" to "national climate adaptation." Each boundary has significantly different values, actions, and possible effects. The objective of boundary reframing is often to energize social or financial investment toward a defined problem, set the largest boundary that encompasses desired behaviors. Reframing a problem (such as the framing of climate change as "global warming") may have the effect of engaging some participants while excluding others, usually for expected benefits ranging from memory, to investment, to publicity.

Framing ensures that a sufficient variety of conceptual design options are considered and tested before selecting a position and (possibly) a purpose. We can consider this shared principle one of *boundary framing* when employed in the definitional stages of a design process. Buchanan's (1992) design technique of placements employs a similar mechanism of repositioning a concept, solution or option in different contexts where a new capacity for interaction or use might emerge. Placements are indicated as the movement of applications of a design concept, from "signs to action," such as an iconic image repositioned in a service function with a new meaning for a user's interaction. The symbolism of an artifact can be "placed" to reframe the purpose of a system by repositioning the function in another setting. The four orders of design (generally communications, artifacts, services, and complex systems) represent possible outcomes for designed functions identified in one context and framed and placed in another. Placement is helped by the designer's strategic ambiguity of the concept, to enable stakeholders to release their stance on preferred outcomes, or to "defactualize" the present to envision alternative future placements. Placements as frames can occur throughout a design process, from strategy to deployment. Consider that even the entrepreneurial concept of the "pivot" is essentially a new placement of an whole product concept after its definition and evaluation.

A primary function of design thinking is to obviate the necessity to analyze a problem's structure and behavior by finding a different problem to resolve than the default, the situation as given. Designers refer to this process as challenging the brief. Paton and Dorst (2011) show how designers modify and negotiate frames of design problem briefs provided to instantiate a design project. Reframing is an abductive reasoning process of identifying new metaphors and a "better problem" to resolve than the issue as given in the brief. Three processes are defined in reframing: (1) Use of metaphor and analogy, (2) Contextual engagement, and (3) Conjecture practices.

Metaphors are creative transformations of the problem to represent its behaviors or related elements as another model considered more familiar to the designers and team. In a design brief, designers might reimagine an abstract requirement (such as a website associated with a product) as another form entirely (such as a museum or analogy of a storybook). Contextual engagement refers to the practice of working with visual or verbal models (or mockups) in narratives that evaluate the functions of the brief within a context of use. Switching contexts enables the designers to reflect on the appropriate fit of the evolving idea in different uses. Conjecture asks multiple "what if" questions of the design model and situation itself. Conjecture can be playful and non-binding, but produces the serious effect of helping stakeholders release preconceptions of the initial frame and situation to allow something novel to emerge.

Reframing is inhibited by three barriers of (1) fixation, (2) a problem-solving mental model of design, and (3) resistance to journey. *Fixation* is a cognitive barrier or bias toward the known, the attachment to a previous idea or course of action. Fixation inhibits reframing as it commits an individual to a single preferred course. The *problem-solving mental model of design* refers to design thinking approaches that conceive of a problem as a target issue to be solved through methods or steps, the very caution raised by Özbekhan and Warfield. *Resistance to journey* is the bias toward reasonableness, or unwillingness to follow an imaginative path to possible transformations of the problem.

Requisite Variety

Theoretically, all ten design principles have a basis in cybernetics or natural systems. Requisite variety represents a foundational cybernetic principle adapted to systemic design. Ashby's (1958) law of requisite variety asserts that the variety in a control system must be greater than or equal to the variety in the system being regulated. In a fairly simple system such as a thermostat regulation of air temperature, all of the possible states of the output system (heating and cooling) are selected by the control unit. Temperature, fan, system settings are equally matched to the system capacities and the control limits the available outputs. In system or service design, requisite variety is observed when the coordination of a system is managed by processes that can adapt to outputs and effects of the system in operation. In complex systems such as corporate organizations, a combination of well-defined regulators (organizational structures), management (human activity systems), and procedures (variety limiters) collectively serve as a control system for the complex operation.

Whether in a social system or information system, the functional complexity of a given design must match the complexity of its target environment. However, in design terms complexity is not desirable, and the *environment* is not an objective reality of physical operations. The environment to which the control system adapts and regulates is the primarily human environment of the system that deploys these system functions. The thermostat is designed to limit the variety available in the mechanical system to the normal limits of human habitation. A user interface limits the full power of an interactive computing system to maximize the preferred ability to perform designated tasks easily.

The popularized notion of requisite variety is expressed by the statement "getting the whole system in the room," applicable to strategic engagements where stakeholders representing every function are expected to contribute. However, in a systemic design context the application of requisite variety to organizations or policy requires an active expansion of the design role from individual planner to collective stakeholders. The Design 3.0 and 4.0 domains extend design roles and skills from individual design decisions (1.0) or even a design team (2.0) to organizational functions (3.0) and communities and stakeholder groups (4.0). According to Espejo (2000) observing requisite variety in management practice becomes a process of attenuating variety among the "very large number of distinctions created within a situation" (2000, p. 2). The manager's control task is aided by amplifying selected distinctions with positive feedback to direct collective attention toward highly-valued outcomes. While hierarchy (structure) has been employed as a classical variety attenuator in most large organizations, Espejo recommends a balance of corporate discipline (i.e., chain of command) with local autonomy to enhance the capacity of the total organization to respond to complexity at the front lines.

There are several distinctions of variety and diversity for decision making in a social system. Christakis and Bausch (2006) state that for dialogue to be valid and lead to effective interventions, requisite variety among the stakeholders for a shared problematic situation must account for social system variety. In dialogic design, the law of requisite variety is applied to ensure the optimal selection of stakeholders in strategic dialogue. The observations made by participants in dialogue must be at least equal to the variety of observations that any other stakeholder group would have made if exploring the same system. Social variety considers all distinctions that could make a difference in outcomes and action in the world, which include the values, positions and stands, affiliations, perspectives, level of power and vulnerability, and so on. An exhaustive account of social variety would be impossible, but the selection of stakeholders by salient and significant determinants can be codified in practice.

A good example of planning for requisite variety was reported in the Imagining Canada's Future project (SSHRC-CRSH, 2013), where the Southern Ontario expert panel was selected from across areas of expertise, urban regions, age ranges, disciplines, sectors, and achieving gender balance. The process for achieving requisite variety in stakeholder selection has been described in numerous other applications of Structured Dialogic Design (Christakis & Bausch, 2006).

Feedback Coordination

Another fundamental cybernetic principle shared by systemics and design is the coordination of feedback, as defined by Wiener (1948) and developed in cybernetics and system dynamics. Negative (compensatory) and positive (reinforcing) feedback loops are distinguished in physical and control theory as designable functions to guide the output performance of a system to conform to desired effects. Feedback processes are conceived as continuous or iterative loops, gathering information from a state, applying control signals to obtain a desired performance, and measuring the difference and coordinating this control to achieve a preferred state. Feedback coordination provides the mechanism that drives the thermostat (a homeostat) in the requisite variety example. Such a simple feedback system represents a first order feedback loop. Second order feedback provides another (meta) control system, usually a human observer, measures and information about the first order system to enable coordination of the feedback system itself.

Product, service, and social design employ feedback coordination in fundamentally similar ways to the principles of cybernetic control. We can define three distinct, applied modes of feedback coordination in design practice. Each of these would have a separate control system (observers or decision team), yet they could be nested within the third order system (organizational) given the design approach.

- First order: System feedback coordination. Feedback designed within the product or system being designed (system control).
- Second order: System management coordination. Feedback systems coordinated to adapt system performance to environmental demands (evaluation and iteration).
- Third order: Organizational management coordination. Feedback coordination within the organization(s) coordinating the system design process (innovation management).

Each of these forms is addressed briefly.

System Feedback Coordination
The first order feedback loops are those control loops (negative feedback) and reinforcers built into the system or product as designed. Negative or control loops are information streams that monitor and control an output, such as the detection and management of very large data files or the prompts to software users to add inputs to an incomplete data record. Positive feedback is the reinforcement of desired system behaviors, such as an active prompt to share an article on social media services, which amplifies the external measures of that object's activity. Delays between feedback and response are minimal or response is immediate.

In a social system context, first order feedback coordinates information between functions among members of the social order. Essentially, most personal conversation for communication purposes about the social system would represent first order feedback.

System Management Coordination
Second order coordination feeds back or changes design functions on the system being designed. System users would not see or be affected by this feedback, but they may provide negative feedback by interaction and commentary that affects design (control) decisions. Most types of user feedback, usability research, and product/system level evaluation are second order feedback systems. Responses to system management feedback are highly variable, usually structured within a development or management lifecycle.

Organizational Management Coordination
Third order feedback observes the performance and values represented in system management, resulting in coordinating responses across the organization. Coordinated management efforts to increase investment or end a product offering are organizational feedback management, such as described in the case of organizational recovery from a significant product failure (Jones, 2008). Negative feedback is coordinated (for example) by performance and market reports, and positive feedback is managed by advertising (increasing usage), marketing (larger adoption in new markets), and direct user engagement.

Feedback processes are found in every interactive, online, service and social system. The distinction of the design principle is that of feedback coordination, or the inclusion of feedback management in a design process. The first opportunities for feedback coordination in a system or service design are when a prototype or “alpha” version undergoes controlled evaluation with informed users representative of the actual system population. Market surveys and customer evaluation are part of the normal monitoring and guidance of feedback in the post-design process. Third order feedback in the social system requires a different approach to coordination, where design managers must allow sufficient time to measure adoption, user responses, and peaks and valleys of use to understand the uptake of the designed process. Consider the complexity of the launch of any major system (such as an electronic health records system), where careful monitoring is required, without making interventions or changes until a planned period of operation and training.

System Ordering

System ordering is an essential function of design activity, as all information, assets, organizations, and social systems are ordered in meaningful ways by human custodians. Designers define humanly-useful structures that enable visibility and salience within complex situations.

Ordering the information and components of a system is a composition process (Nelson & Stolterman, 2012), which refers to the fact that authorial choices are made by designers or actors in managerial roles. Ordering defines the relationships of objects, system components, or abstract concepts to each other in a systematic way. The ordering of relations within a system set creates a compositional unity.

The design of data structures and information representations enables the ordering of coherent patterns and information flows that afford the recognition of meaningful relationships by an observer. Ordering activities define ideal system types and components, as in the specification, mapping and information structuring of planning architects and information architects.

An organization or policy system follows the same principles of ordering for compositional unity. The composition of organizations, relating roles and functions within hierarchies and networks, can be similarly viewed as a designing activity of management. Defining and managing organizational structures and business processes is a systemic ordering activity.

All systems are described as manifestations of order. Systems are represented as abstract organizations of artificial or natural ordering functions, and as such these organizations can be designed. Systems are designed by defining relations, reframing boundaries, and changing hierarchies and roles. The properties and services provided by social and information systems can be ordered by logical and creative structuring. Ordering systems enable the relating of placements across design concepts to achieve a well-integrated design purpose. Order functions range from the most minute and specific task (such as defining data types) to the system-level ordering of laws and transnational agreements.

In both design and systems contexts, ordering can be a recursive process. Systems are designed to instill and sustain new ordering systems, such as information technologies, software, or policies into a social or organizational context. These contexts require the structural definition of ordering and are maintained by ordering systems in future development. Therefore, orders endure through systems, which maintain ordering structures for the duration of expected operations. The multiple ordering systems within an electronic health records (EHR) system, for example, reveal an infrastructure of ordering systems within the interactive software platform. Medical ontologies (such as MEDCIN), databases (e.g. MUMPS), and classification coding systems (e.g. ICD-10 disease and procedure list) are incorporated into the larger EHR systems. These ordering systems are separately maintained, yet offer a core standard reference system used by the entire EHR process.

Generative Emergence

Emergence is a quality of complex adaptive systems whereby a higher, coherent level of organization arises from the interaction of system components. The emergent behaviors are those perceived to be novel or distinct from the mere collection of properties associated with the parts. Emergence properties in complex social systems are considered co-occurring with intentional, purposeful behaviors. The emergent characteristics may, as in natural systems, reveal inherent purposes of the system.

Emergence appears to be universal, as phenomena can be observed at virtually every level of scale from the cellular to the galactic. Emergent behaviors are exhibited in real time (the cyclic flashing of fireflies), in processes (the emergence of butterflies from cocoon gestation), and over periods of time (stock market wave patterns). As a design principle emergence shares with complexity theory the perspective of biomimetic observation, or simulation of natural processes. While emergence may display an unintended purpose, a signal characteristic of emergence is that of capabilities only achieved by emergence (van Alstyne & Logan, 2007).

> We noted that emergence refers to a new set of properties that arise from a new arrangement of the components of an entity that did not pertain to the individual components. The design of an entity, then, is the assemblage of a set of components that is able to achieve a function or purpose that the components by themselves cannot achieve (2007, p. 128).

For example, network effects in large social networks display emergent qualities that cannot be designed or planned in the absence of large numbers of active participants. For example, the Twitter social networking service was not intentionally designed as a comprehensive product. For at least two years before its network grew to sufficient scale, users of the social network service Twitter generally employed it as a lightweight resource for posting brief texts expected to be followed by a small number of known followers. As the number of users grew exponentially (after 2009) the emergence of communicative norms and content forms led to standards for web links, account identity, and network interaction norms. Because the basic Twitter architecture remained simple and standards were established, aftermarket innovations such as Tweetdeck and Hootsuite led the market for full-featured interfaces, surpassing Twitter's product development. While Twitter may not have produced a sustainable commercial product, its architecture demonstrates generative emergence—the medium enables other products and features to emerge and evolve.

The Occupy movement was observed as an emergent social system. With no designated leaders or organizers, it grew from the simple initial conditions of an email to a large mailing list suggesting a protest at New York's Wall Street area. The resulting local protest was copied by emergent groups in many other North American cities, which cooperated loosely with each other to maintain a continued presence in their chosen physical locations over the autumn of 2011. Among the many emergent behaviors that grew from the diverse coalition of participants was a unique communication protocol for public speaking, called the General Assembly. The "people's mic" process of speaking in phrases repeated by the audience was not a designed process, but an adaptation to the (New York location's) restriction on amplification in the mixed-residential area. It was one of many generative behaviors to develop during the social movement's encampment period.

Nelson and Stolterman (2012) define two protocols of *compositional* and *created* emergence in systemic design, which further distinguish generative emergence. Compositional emergence manifests in design activity as an outcome of *ordering*, or the construction of artificial micro-systems for adapting an artifact to environments. Consider an example such as metadata information hierarchies as ordering systems for a potentially large number of end-use information artifacts. Compositional emergence results from a designed formulation of relationships, categories, ideal types, and structures *for* organization.

Created emergence manifests from *organizing* systems, which include physical connections, designed forms, organizing processes and the synergies that emerge from among these functions. In systemic design, these connections among forms are anticipated, visualized, and represented in artifacts and systems. Yet there are real differences between the protocols. While the Twitter example above was a case of ordering, without much of an organizing system, the Occupy example represents an almost pure organizing protocol leading to created emergence.

Compositional emergence is never designed in a blank-slate environment. Desirable emergent qualities in artifacts and systems evolve from a pre-existing social or use context that gives shape and direction to an innovation. This is what Ciborra called *formative contexts* (Ciborra & Lanzara, 1994) or the pre-existing conditions of organizations, social systems and their norms, learned IT, and information-based work practices. A formative context is similar to the "installed base" that a new system attempts to reconfigure. New forms and structures will be necessarily shaped to adapt to the contexts of use, existing environments, and markets. The generative emergence arising from connecting new practices to formative contexts may not be recognized for a considerable duration, as systemic delays in feedback among connections will take time to resolve and recur. Also, emergence in human behavior is extremely imprecise without an a priori observation protocol that measures (expected) emergent behaviors against the baseline of the formative context.

A social research protocol must therefore measure emerging *figure* behaviors against a pre-existing *ground* of ongoing action and meaning, recognized as the context of its ground. The design principle, consistent with designing for emergence, suggests we explore the environment during highly interactive phases when the effects of perturbations of relationships can be observed and reconfigured by feedback to achieve anticipated outcomes.

Continuous Adaptation

The temporal pacing and duration of social systems are as important as the design of structures, processes and relationships. System maps are often designed as timeline models representing the relationship of design concepts to activity systems (e.g., service journeys) or temporal scenarios (e.g., long-range foresight models). One of the common errors in systemic design is the assumption of temporal consistency, that current system processes will continue unimpeded into an indeterminate future time, subject to the next (planned) intervention. The reality of complex/social systems shows that human observers are unable to determine temporal bifurcations, where processes diverge unexpectedly or where social regimes break down.

Social systems may be self-organizing, but they are not self-*ordering* systems. Organizational and institutional systems adapt the environmental demands through individual responses, and communication protocols maintain organizational integrity. However, collective evaluation or innovation remains limited or impossible without continuous adaptation to environments, societal changes, markets, and system participants. Social systemic design requires a continuous evaluation (scanning, measuring, judging) to assess systemic delays, intention drift, time-dependent functions, the diffusion of change and adoption of strategies. Stakeholders in different design and monitoring roles consciously identify variations over time, signal the onset of emergent situations, and co-design adaptive responses. Such adaptive monitoring is essential for organizational resilience and strategic flexibility.

Continuous adaptation maintains the preferred system purpose and objectives (or desiderata) throughout the lifecycle of adaptation, conformance to environmental demands, and related system changes. Effective systemic design applies the principle of continuous adaptation throughout the design process, from the phases of system design and development through deployment and operation. By incorporating cyclic feedback deeply into the social practices of the host organization, organizations and systems can become resilient to unforeseeable environmental requirements and system breakdowns. A good example of continuous adaptation in a complex service might be the strategic development of the multiple online stores and features incorporated into Amazon.com since its founding. Amazon launched with a strong focus on books and media, and developed its retail outlets by adapting to important market segments. It has continuously and almost imperceptibly adapted over its entire history, in its aim to become the world's largest and most comprehensive online retail center.

Self-Organizing

Self-organizing is a central principle developed in systems theories ranging from Wiener's cybernetics (1948) through Varela, Maturana, and Uribe (1974) biological theories of adaptation and autopoiesis, autopoietic social systems (Luhmann, 1986), to more recent complex adaptive systems theory (Holland, 1995).

Social systems are self-organizing human interaction systems that develop (evolve) through learning and flexible responses to changing circumstances. Human systems are self-organizing in the sense that no planned external inputs (from monitoring, for example) respond to human and environmental feedback as any type of living system. Even Ashby (1962) argued for a general systems principle of limited self-organization, that "every … dynamic system obeying unchanging laws will develop 'organisms' that are adapted to their "environments." This organizing principle was based on the observation that even simple machines actively select states of equilibria. When disturbed, a system seeks to stabilize an interrupted state by locating an equilibrium that accommodates the environment and the set of available states. In systems with rich variety (social systems) the available states would be numerous and support self-organization in that capacity.

Jantsch (1975) linked self-organizing, self-determination and evolutionary design as core systems principles. Jantsch's principle of self-organizing systems defined an evolutionary drive that used creative processes to break through system boundaries, and through self-transcendence, reached renewed states of new organization. This very process was observed as a design activity, as a natural process of interaction with the physical, social, and cultural (spiritual) worlds of humanity, serving an evolutionary purpose. Two related processes were articulated. Self-organizing serves a positive feedback or reinforcing process that enables creative organization of social systems by its participants. The cybernetic feedback processes of negative feedback (guidance) serves a self-*adaptation* capacity, the regulation of behaviors within preferred or sustainable limits.

The systems principle of self-organizing enables the design of actions that increase awareness, incentives and social motivations to accelerate organizing behaviors. These actions result in the effect of enacting reinforcing behavior loops and drawing additional participants into those loops. These processes can be specifically designed to increase participation. Social participation reinforces the self-organization of co-created content and purposeful interaction within the boundaries and norms of the social system.

In a design context, self-organizing is related to generative emergence, as it reinforces socially expected behaviors that lead to greater collective effects. Some of these emergent effects, such as network power or identity formation, may be preferred by organizers (designers), but these outcomes cannot be guaranteed by designed actions. Networks are self-organizing because the individual behaviors of thousands of market or network participants are predicated on individual expectations of the participation of others. The resulting communication network is considered self-organizing as a collective phenomenon. We may not be able to state that the network or system behaviors were *designed*, but rather that the conditions that created the network were carefully designed to instill those behaviors. The essential form of network creation arises in conversation, a self-organizing (autopoietic) outcome of languaging:

> In the case of human beings our particular manner of living is to converse, that is, to live together in the coordinations of coordinations of doings and emotions, and everything that humans do happens in networks of conversations (Yanez & Maturana, 2013, p. 79).

A prominent example exists in the popular group dialogue process *Open Space* (Owen, 2008). The guiding parameters of Open Space Technology are entirely based on the process of social self-organizing, through self-selection of small groups that form emergent organizational systems.

> In the world of self-organizing systems (the only world we have, I believe), organization will emerge (or not) and no amount of effort on our part to organize things will have any useful effect. Under the best of circumstances, our efforts will be a waste of time when the emergent organization overcomes our design (Owen, 2008, p. 128).

Open Space small groups are analogous to Ashby's intelligent organisms adapting to and from their environments. The principles of dialogue are not entirely self-organizing however. While groups may form an emergent organization, that organization will not be an ideal form for effective action. While each and every dialogue may reveal self-organization, the self-organizing is not an experienced quality of the process. The quality and outcome of dialogue requires a conscious process of initiating and coordinating the flows of conversation. Numerous social research observations (Christakis & Bausch, 2006; Warfield, 1995) have demonstrated the pathologies of within-group behavior. Within-group dialogue requires a designed structure and design process to enhance variety, facilitate agreements and mitigate the selection of power within groups.

As a *design* principle, self-organization reminds us of the limited capacity of the individual designer as a formative agent, or an instrumental first-actor toward progressive action. Higher complexity social projects require cooperative organization among multiple actors; indeed some social systems theories (e.g. Christakis & Bausch, 2006) consider all stakeholders as relevant *designers*. The social design practices of dialogue and generative facilitation may be considered self-organizing in principle. Still we acknowledge the particular need for "designerly" actions in material and composition required to realize desired organizational outcomes. Such projects require the skillful means of system ordering, information design, sociotechnical design, and designed communications strategies.

Discussion

Systems theory and design thinking both share a common orientation to the desired outcomes of complex problems, which is to effect highly-leveraged, well-reasoned, and preferred changes in situations of concern. A central difference in perspective is that systems thinking (resulting from its theoretical bias) promotes the understanding of complex problem situations independently of interventions or solutions. The primary systems science disciplines manifest an analytical bias. Design thinking, while not overlooking the imperative toward understanding, prefers an action-first generative bias. Traditional design history, until the most recent (fourth) generation of design methods, presented design as a planning process, oriented to industrial design, where (analytical) problem definition preceded solution.

Systems theories are formulations of frameworks, models, and reasoning practices intended to enable effective problem solving at the systemic scale of application. Systems thinking has emerged as a perspective toward effective problem solving and associated reasoning patterns for complex interconnected (wicked) problems. Design thinking, on the other hand, can be considered a continuously interpreted perspective toward action on intended outcomes, using iterative, successive approximations with highly differentiated artifacts. While these perspectives may be seen as compatible, their co-development and practice presents a contemporary challenge.

Current models of design thinking have overemphasized the generative impulse, to a great extent resulting from the decreased costs of virtual invention and software production. Technologies greatly influence the preference of process and theories—for instance, the hard science approach of simulation modeling has strongly influenced the system dynamics school of systems thinking.

Design thinking has been influenced by rapid prototyping culture. When virtual trials and failures are cheap, multiple prototypes are less expensive than in-depth analysis and research. However, this design thinking bias leads to a short-term bias that rewards immediate responses to prototypes. For industrial products, those bias' risks are minimal. However, for complex social systems a prototyping mindset evaluates component subsystems (at best) selected by a saliency bias. This bottom-up approach fails to acquire a system-level understanding and even erodes a holistic view. New system relationships are formed through iterative trials and informal sample evaluations, but current relationships are not necessarily discovered, leading to significant gaps in systemic understanding.

Systems Thinking about Design Thinking

A contemporary viewpoint encouraged by the participatory viewpoint of multidisciplinary design is that "everyone is a designer now." The fourth generation of design methods promotes generative and participatory tools and mindsets. Pourdehnad et al. (2011) note that a key difference between systems and design thinking is that, for social systems practices, the stakeholders are the designers. The stakeholders in design practices are observed and engaged by designers, and designers retain the judgment and decision rights for the artifacts or services being designed for stakeholders. They recommend an integration of viewpoints toward the ideal of co-creative practice.

Unlike previous stages of design methods, the fourth generation has not accepted a leading systems theory influence. Rather, design studies today tend to follow an ambiguous version of complexity theory, rendered without citations or methodological influence. Due to the implicit skepticism toward methods from previous generations, the previous systems influences associated with design methods have become ignored and underused, leading to insufficient competency to evolve or reconfigure these rigorous systems methods with new practices.

Yet even professional design practice struggles with learning the current profusion of design and organizational methods, as a confusing diversity of approaches is apparent. The codified meaning of "design thinking" ranges widely between the domains of design education, business design, design consulting, and systemic design. Without guidance from some systemic rigor the new schools of design thinking are vulnerable to current management trends as well as market-oriented practices such as *agile* and *lean development*.

Design thinking has been promoted as a powerful practice for aligning organized action with social goals, including social innovation (Brown & Wyatt, 2010) and business management and education (Dunne & Martin, 2006). For nearly a decade, hopes have been high for the results of this contemporary change in mindset, organizing, and pedagogy. Yet current institutions and corporate practices have not demonstrated significantly novel evolutions in policy or business that have benefitted the acknowledged socially complex problems. Traditional financial and market measures of value continue to drive most organizational performance, employment, and the real economy. There may be a significant mismatch of problem scale and design method and practice that design thinking fails to address. Yet this very gap (between problem and practice) is within the understood domain of systems thinking.

Systems thinking enjoys over half a century of intellectual development, and while inclusive of a diverse range of scholars and practices, its solid founding in systems theory guarantees its authority and maturity as an intellectual platform for problem solving. Design thinking shows a robust history (either roughly 20 years of 50 years, depending on definitions), yet the lack of scholarly follow-through in the field has left its intellectual development wanting. Whereas systems theories were developed in keen awareness of the relative contributions from the scientific community, presentations of design thinking, perhaps due to its genesis in design traditions, rarely cite any precedent or theoretical influences.

The possibility exists that design thinking will fail to meet the scope and magnitude of the social and systemic issues facing humanity and societies today. Two Greek terms, *hubris* and *panacea*, might be chosen to characterize the earlier attempts to navigate understanding and effectively intervene in complex social systems. Hubris fits, because many are led to believe that design thinking and methods are sufficient for a problem complexity that cannot be comprehended individually. Panacea, because design thinking risks becoming a cure-all methodology adopted not only by design disciplines but by business, information, and technology disciplines with unrealistic expectations for results.

Without a significant basis for theoretical support, such as systems theory, design thinking is at risk of becoming a management fad, (Bendor et al., 2009) especially as it becomes widely adopted as a strategy for creative inspiration and innovation by mainstream corporate organizations. A major difference with systems thinking is revealed in this comparison. Systems thinking claims a clear theoretical base from a 50 year or more history of systems theory development in the literature. Yet it remains a complex soft technology and generally is not considered a tool for competitive advantage, as it cannot easily be converted to instrumental methodology or business strategy. Design thinking has minimal support from scholarly research and a shallow literature, yet it has become readily adopted in all sizes and types of firms, often explicitly in search of competitive advantage. The adoption of management practices, because of their novelty or visibility in reference groups, is indicative of management fashion (Mol & Birkinshaw, 2009).

Design thinking may succeed as a management innovation because it is presented in terms of practices that yield deliverable representations that serve as boundary objects (Star & Griesemer, 1989). Boundary objects are artifacts that can be claimed and appropriated by participants in adjacent or overlapping disciplines, and therefore aid organizational learning by transferring knowledge and ideation across boundaries.

Systems thinking has not produced a body of artifacts or practices adopted widely in organizations. There are few acknowledged boundary objects, or shared representations, recognized as useful across disciplines in organizational settings. This gap reveals a significant opportunity for promoting practices for systems-oriented artifacts such the Gigamap (Sevaldson, 2011) and the influence map of systemic relationships (Christakis & Bausch, 2006). Such visual models represent many of the systemic design principles and are formulated for strategic contexts that lend credibility and meaning to their adoption.

Conclusion

The systemic design orientation enables a complementarity of design and systems theory for complex social and service systems, the domains identified for Design 3.0 and 4.0. As research and practices develop, the influence of this generation should diffuse into products and services design. A handful of books and articles have excavated this emerging territory, but it would be premature to indicate that a recognized interdisciplinary field has taken hold. While several graduate courses and programs exist, they have not yet yielded definitive research streams.

The design principles representing the complementarity of essential systems and design axioms are judgments based on perspectives of theory, practice and literature, and are not ultimately definitive. They are descriptive guidelines to orient designers toward an awareness of systemic principles in the more complex problem areas being faced by clients and design teams. They are also meant as guidelines to systems theorists to intimate or provoke more powerful theories of systemics and complexity for design, management, and other reflective practices.

An earlier presentation of systemic design concepts (Jones, 2012) described a similar basis of principles for systemic methods. A design language provides a framework and taxonomy guiding the placements of information, objects and meaning in a given domain, in this case, service design in healthcare. These principles combined system functions with human-centered design methods for social systems, integrating system principles with design methods. Five design methods based on systemic practice were suggested, which enable design interventions within a complex (Design 3.0–4.0) domains. To summarize, these include:

- Human-centeredness: Design in social systems requires research and design methods that contribute understanding of human activity and human concerns.
- Convening stakeholders: Design participants must have a personal stake in the outcome of the intervention, or the resulting products will fail from lack of resonance to authentic stakeholder commitments.
- Dialogic process: Dialogic processes enable the connection of diverse stakeholders to the joint processes of inquiry and design. Higher complexity problem areas demand structured approaches to dialogue that enable participants to achieve a collective systems view.
- Iterative inquiry: Systems inquiries require the learning and re-integration of new thinking that occurs over successive explorations and exchanges.
- Multiple design actions over time: As with research and inquiry, design and interventions require multiple methods that explore the full dimensionality of a problem over the period of inquiry.

This chapter has focused on the systemic principles to the exclusion of methods. Further work is called for in developing the design languages and next-generation systemic design methods consistent with the design principles. Further research should also evaluate the principles against other design situations and systems theories. There may be other formulations of principles more generally advantageous to complex design problems, discovered through application and practice research. The current chapter provides a series of principles which serve as guidelines for systemic practice. It outlines a framework of principles that can lead practitioners toward effective and new research and design approaches. Finally, these principles are pointers toward further research and inquiry into systemic design as a developing disciplinary area.

References

Ackoff, R. L. (1993). Idealized design: Creative corporate visioning. *OMEGA, 21*(4), 401–410.

Ackoff, R. L. (2004). *Transforming the systems movement. Third International Conference on Systems Thinking in Management*, May 19, 2004, Philadelphia, PA.

Ackoff, R. L., & Emery, F. E. (1972). *On purposeful systems: An interdisciplinary analysis of individual and social behavior as a system of purposeful events*. Chicago: Aldine-Atherton, Inc.

Alexander, C. (2004). *The nature of order: An essay on the art of building and the nature of the universe*. London: Routledge.
Ashby, R. (1958). Requisite variety and its implications for the control of complex systems. *Cybernetica, 1*(2), 1–17.
Ashby, W. R. (1962). Principles of the self-organizing system. In H. Von Foerster & G. W. Zopf Jr. (Eds.), *Principles of Self-Organization: Transactions of the University of Illinois Symposium* (pp. 255–278). London: Pergamon.
Banathy, B. H. (1996). *Designing social systems in a changing world*. New York: Plenum.
Baskerville, R. L., Pries-Heje, J., & Venable, J. (2009). Soft design science methodology. In *Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technology (DESRIST '09)* (pp. 1–11), Philadelphia.
Bendor, J., Huberman, B. A., & Wu, F. (2009). Management fads, pedagogies, and other soft technologies. *Journal of Economic Behavior and Organization, 72*(1), 290–304.
Bousbaci, R. (2008). “Models of man” in design thinking: The “bounded rationality” episode. *Design Issues, 24*(4), 38–52.
Brown, T. (2009a). *Design for social impact*. New York: Rockefeller Foundation: IDEO.
Brown, T. (2009b). *Change by design: How design thinking transforms organizations and inspires innovation*. New York: HarperBusiness.
Brown, T., & Wyatt, J. (2010). Design thinking for social innovation. *Stanford Social Innovation Review, Winter, 2010*, 31–35.
Buchanan, R. (1992). Wicked problems in design thinking. *Design Issues, 8*(2), 5–21.
Christakis, A. N., & Bausch, K. C. (2006). *How people harness their collective wisdom and power to construct the future in co-laboratories of democracy*. Greenwich: Information Age.
Ciborra, C. U., & Lanzara, G. F. (1994). Formative contexts and information technology: Understanding the dynamics of innovation in organizations. *Accounting, Management and Information Technologies, 4*(2), 61–86.
Cisneros, R. T., Hisijara, B. A., & Bausch, K. C. (2013). *Strategic articulation of actions to cope with the huge challenges or our world: A platform for reflection*. Atlanta: Institute for 21st Century Agoras.
Collopy, F. (2009). *Lessons learned: Why the failure of systems thinking should inform the future of design thinking*. Fast Company, June 7, 2009. Retrieved from fastcompany.com/1291598/lessons-learned-why-failure-systems-thinking-should-inform-future-design-thinking
Cross, N. (1990). The nature and nurture of design ability. *Design Studies, 2*(3), 127–140.
Cross, N. (2001). Designerly ways of knowing: Design discipline versus design science. *Design Issues, 17*(3), 49–55.
Crutzen, P. J. (2002). Geology of mankind. *Nature, 415*, 23.
Dubberly, H. (2008). Design in the age of biology: Shifting from a mechanical-object ethos to an organic-systems ethos. *Interactions, 15*(5), 35–41. doi:10.1145/1390085.1390092.
Dunne, D., & Martin, R. (2006). Design thinking and how it will change management education: An interview and discussion. *Academy of Management Learning and Education, 5*(4), 512–523.
Espejo, R. (2000). *Giving requisite variety to strategic and implementation processes: Theory and practice*. Lincoln: University of Lincolnshire and Humberside.
Evenson, S., & Dubberly, H. (2010). Designing for service: Creating an experience advantage. In G. Salvendy & W. Karwowski (Eds.), *Introduction to service engineering* (pp. 403–413). New York: Wiley.
Fox, W. (1995). Sociotechnical system principles and guidelines: Past and present. *Journal of Applied Behavioral Sciences, 31*, 91–105.
Fry, T. (2009). *Design futuring: Sustainability, ethics and new practice*. Oxford: Berg.
Fuller, R. B. (1981). *Critical path*. New York: St. Martin’s.
Gharajedaghi, J. (2011). *Systems thinking managing chaos and complexity: A platform for designing business architecture*. Burlington: Morgan Kaufmann. Retrieved from http://site.ebrary.com/id/10480742

Glenn, J. C., Olsen, T. D., & Florescu, E. (2012). *2012 State of the future*. Washington, DC: The Millennium Project.

Holland, J. (1995). *Hidden order: How adaptation builds complexity*. Reading: Addison-Wesley Publishing Company.

Jackson, M. (2010). Reflections on the development and contribution of critical systems thinking and practice. *Systems Research and Behavioral Science, 27*, 133–139.

Jantsch, E. (1975). *Design for evolution: Self-organization and planning in the life of human systems*. New York: George Braziller.

Jones, P. H. (2008). *We tried to warn you: Innovations in leadership for the learning organization*. Ann Arbor: Nimble Books.

Jones, P. H. (2009). Learning the lessons of systems thinking: Exploring the gap between thinking and leadership. *Integral Leadership Review, IX*(4), 1–8.

Jones, P. H. (2012). *Design for care: Innovating healthcare experience*. Brooklyn: Rosenfeld Media.

Jones, P. H., & Van Patter, G. K. (2009). Design 1.0, 2.0, 3.0, 4.0: *The rise of visual sensemaking*. New York: NextDesign Leadership Institute (article). Retrieved from http://humantific.com

Krippendorf, K. (1996). A second-order cybernetics of otherness. *Systems Research, 13*(3), 311–328.

Latour B. (2008). A cautious Prometheus? A few steps toward a philosophy of design. *Meeting of the Design History Society*, September 3, 2008, Falmouth, Cornwall.

Luhmann, N. (1986). The autopoiesis of social systems. In F. Geyer & J. van der Zouwen (Eds.), *Sociocybernetic paradoxes*. London: Sage.

Meadows, D. H., Meadows, D. L., Randers, J., & Behrens, W. W. (1972). *The limits to growth: A report for the Club of Rome's project on the predicament of mankind*. New York: Universe Books.

Metcalf, G. S. (2010). Service as mutualism: A question of viability in systems. *Service Science, 2*(1/2), 93–102.

Mol, M. J., & Birkinshaw, J. (2009). The sources of management innovation: When firms introduce new management practices. *Journal of Business Research, 62*(12), 1269–1280.

Nadler, G., & Hibino, S. (1998). *Breakthrough thinking: The seven principles of creative problem solving*. Roseville: Prima Lifestyles.

Nelson, H. (1994). The necessity of being undisciplined and out of control: Design action and systems thinking. *Performance Improvement Quarterly, 7*(3), 22–29.

Nelson, H. G., & Stolterman, E. (2012). *The design way: Intentional change in an unpredictable world* (2nd ed.). Cambridge: MIT.

Ostrom, E. (1985). Actions and rules. *Workshop in Political Theory and Policy Analysis*, February 28, 1985, Champaign, IL. Bloomington, IN: Indiana State University.

Ostrom, E. (2009). Design principles of robust property-rights institutions: what have we learned?. Property Rights and Land Policies. K. Gregory Ingram, Yu-Hung Hong, eds., Cambridge, MA: Lincoln Institute of Land Policy.

Owen, H. (2008). *Wave rider: Leadership for high performance in a self-organizing world*. San Francisco: Berrett-Koehler Publishers.

Özbekhan, H. (1968). *Toward a general theory of planning*. Santa Monica: System Development Co.

Özbekhan, H. (1969). *The predicament of mankind: A quest for structured responses to growing world-wide complexities and uncertainties*. New York: Club of Rome.

Özbekhan, H. (1970). The predicament of mankind: A quest for structured responses to growing world-wide complexities and uncertainties. *Club of Rome proposal*. Retrieved from http://globalagoras.org/publications

Paton, B., & Dorst, K. (2011). Briefing and reframing: A situated practice. *Design Studies, 32*(6), 573–587.

Pourdehnad, J., Wexler, E. R., & Wilson, D. V. (2011). Systems and design thinking: A conceptual framework for their integration. In *Proceedings of the 55th Annual Meeting of the ISSS,* July 17–22, 2011, Hull, UK.

Rittel, H. W. J., & Weber, M. (1973). Dilemmas in a general theory of planning. *Policy Sciences, 4*, 155–169.
Sanders, E. B. N., & van Stappers, P.-J. (2013). *Convivial toolbox: Generative research for the front end of design*. Amsterdam: BIS Publishers.
Sevaldson, B. (2011). *Gigamapping: Visualization for complexity and systems thinking in design*. Helsinki: Nordic Design Research Conference.
Simon, H. E. (1969). *The sciences of the artificial* (1st ed.). Cambridge: MIT.
Slaughter, R. (1999). *Futures for the third millennium: Enabling the forward view*. Sydney: Prospect.
SSHRC-CRSH (2013). *Imagining Canada's future*. Technical Report. Ottawa, Canada: Government of Canada.
Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science, 19*(3), 387–420.
Stockholm Memorandum. (2011). Stockholm Memorandum. *Third Nobel Laureate Symposium*, Stockholm, Sweden, May 16–19, 2011.
Upward, A. (2013). *Towards an ontology and canvas for strongly sustainable business models: a systemic design science exploration*. Unpublished thesis. York University, Toronto, Canada
van Alstyne, G., & Logan, R. (2007). Designing for emergence and innovation: Redesigning design. *Artifact, 1*(2), 120–129.
van Patter, G. K., Pastor, E., & OPEN Innovation Consortium. (2013). *Innovation methods mapping: De-mystifying 80+ years of innovation process design*. New York: OPEN Innovation Consortium.
Varela, F., Maturana, H., & Uribe, R. (1974). Autopoiesis: The organization of living systems, its characterization and a model. *Biosystems, 5*, 187–196.
Warfield, J. N. (1990). *A science of generic design: Managing complexity through systems design*. Ames: Iowa State University Press.
Warfield, J. N. (1995). Spreadthink: Explaining ineffective groups. *Systems Research, 12*(l), 5–14.
Warfield, J. N. (1999). The problematique: Evolution of an idea. *Systems Research, 16*, 221–226.
Warfield, J. N. (2001). Measuring complexity. *Integrative Sciences Working Paper*. Retrieved from http://digilib.gmu.edu/dspace/handle/1920/3411
Wiener, N. (1948). *Cybernetics, or control and communication in the animal and the machine*. New York: Wiley.
Winograd, T., & Flores, F. (1986). *Understanding computers and cognition*. Norwood: Ablex.
Yanez, X. D., & Maturana, H. (2013). Systemic and meta-systemic laws. *Interactions, 20*(3), 76–79.