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Rendering Systems Visible for Design: Synthesis Maps as Constructivist Design Narratives

Abstract Synthesis maps integrate research evidence, system expertise, and design proposals into visual narratives. These narratives support communication and decision-making among stakeholders. Synthesis maps evolved from earlier visualization tools in systemics and design. They help stakeholders to understand design options for complex sociotechnical systems. Other visual approaches map complexity for effective collaboration across perspectives and knowledge domains. These help stakeholder groups to work in higher-order design contexts for sociotechnical or human-ecological systems. This article describes a constructivist pedagogy for collaborative learning in small teams of mixed-discipline designers. Synthesis mapping enables these teams to learn systems methods for design research in complex problem domains. Synthesis maps integrate knowledge from research cycles and iterative sensemaking to define a coherent design narrative. While synthesis maps may include formal system modeling techniques, they do not require them. Synthesis maps tangibly render research observations and design choices. As a hybrid system design method, synthesis maps are a contribution to the design genre of visual systems thinking.

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1 Donald A. Norman and Pieter Jan Stappers, "DesignX: Complex Sociotechnical Systems," *She Ji: The Journal of Design, Economics, and Innovation* 1, no. 2 (2015): 83–106, DOI: https://doi.org/10.1016/j.sheji.2016.01.002.

2 Birger Sevaldson, "GIGA-Mapping: Visualisation for Complexity and Systems Thinking in Design," in *Proceedings of Nordic Design Research Conference 2011: Making Design Matter* (Helsinki: NORDES Digital Archive, 2011), 1–20, available at http://www.nordes.org/opj/index.php/n13/article/view/104; Birger Sevaldson, "Systems Oriented Design: The Emergence and Development of a Designerly Approach to Address Complexity," in *Design Learning for Tomorrow: Design Education from Kindergarden to PhD. Proceedings of the 2nd International Conference for Design Education Researchers*, ed. Janne B. Reitan, Ingvild Digranes, and Liv M. Nielsen (Oslo: Høgskolen i Oslo og Akershus, 2013), 1–22.

Introduction

Synthesis mapping is a practice that supports learning, representation, and communication of perspectives, actors, and relationships in complex system challenges. Its purpose is to promote shared understanding while examining the design options available in these systems. Many design researchers and educators seek methods for the multidisciplinary study of complex sociotechnical systems, while advanced design students and teams must frame and communicate collective understandings and design proposals that address complex challenges. Designers today collaborate with colleagues from a wide range of disciplines. Each plays a part in formulating and developing the products, services, and systems of a complex, increasingly instrumented society.[1] The synthesis map emerged from earlier practices in graduate design education as a method for creating visual narratives to support these emerging concerns.

Today's highly integrated, complex platforms and data-driven systems demand a wide range of skills and knowledge in design, research, facilitation, and craft. Systems design requires more than design and research. It requires many kinds of expertise to create complex projects in public service delivery, health care, architecture, urban design, and other large sociotechnical arenas. In recent years, design education made significant strides toward developing specialized graduate programs and transdisciplinary courses to meet these needs. While many design schools offer advanced practice courses in such emerging design disciplines as service design and interaction design, however, effective methods for designing and representing socially complex systems have not kept pace. These schools do not teach systemic methods widely or consistently.

Systemic design, integrated design, and transition design all contribute to new theory, to design methods, and, increasingly, to professional practice. Among these transdisciplinary modes of systems design, however, there are few generally accepted methods similar in application to the service blueprint or journey maps in service design. The Gigamap[2] and the synthesis map are two types of system maps developed for working with socially complex problems. With synthesis maps we employ different design practices and pedagogies from the studio approach used for the Gigamap method. Much of the difference is due to structural constraints in the design education programs that employ these methods. Despite differences in educational objectives, synthesis mapping follows a coherent approach that complements the well-known Gigamap method.

As the title of this article suggests, the systems we describe are only as tangible as our renderings. Synthesis maps are a type of system map that a team of designers and researchers team develops in a course studio or professional project. Synthesis maps differ significantly in size, visual appearance, and application from the formal models used in systems engineering and analytical traditions. The purpose of a synthesis map is to articulate the processes and relationships that are vital to stakeholders of the system. Visual narrative enables synthesis maps to reach broader audiences than analytical models can. By increasing interest and usage, synthesis maps – along with Gigamaps, process maps, or system maps – have become useful design tools. These maps engage stakeholder groups. They represent perspectives and enable stakeholders to understand systemic problems. Synthesis maps define salient problems and design options of interest, helping observers to develop sophisticated mental models.

System maps – natural, social, or technological – represent relationships among parts. Human representations of systems are necessarily incomplete, biased, and biasing. We make necessary compromises in the pragmatics of system mapping because these maps represent functional relationships that people construct as they reach agreement using language. If we observe the social learning and formation of synthesis maps in teaching and design, it is a constructivist inquiry. It involves developmental learning as map-makers grapple with multiple problems and ways to represent them.

System mapping involves constructivist learning in action. It demonstrates the reflective practices and conversational structures used to build knowledge and organize the factors of a system as conceived in the world.[3] During the mapping process, designers continually interrogate the meaning of relationships in a system as they externalize and represent them. This is constructivist learning in action. The act of framing defines the boundaries of a system. To create a map, stakeholders and those who facilitate the mapping process select evidence from various sources while selecting the rationale for the knowledge they acquire through conversations about the social systems they find in the world.

Designers and other experts form synthesis maps through conversational inquiry. Map-makers must also account for feedback from map users or stakeholders. Maps are subject to the choices and judgments of designers who attempt to communicate in the language of a system of interest. These are often systems for which we have little a priori knowledge. Over time, the synthesis process reflected in sketches and mapping helps us to construct a shared mental model that enables a profound awareness of the relationships abstracted in the map. Even though the map is a tangible design artifact, we argue that the intended users of a map do not perceive it as a static object, but as an interactive model of their system of concern. For participants within the envisioned system, the artifact triggers a sustained discourse generated by the distinctions in the map itself. Most other evidence products, including technical reports and presentations, rarely affect an organization's view of a system: reports are commonly shelved; external presenters' ideas are easily ignored. However, a visual narrative challenges the reader with a systemic perspective – a point of view that may not be perfectly correct, but cannot be dismissed as irrelevant.

Design Rationale

The disciplines of design, architecture, and urban planning, have historically developed visual compositions and associated visual languages to frame and illustrate complex systemic problems. Mapping methods emerged from a myriad of visual design tools and representation frameworks to generate complex problem understanding, visual analysis, and solution finding. Synthesis maps are an evolution of what Edward Tufte refers to as design strategies for presenting information about causality and process.[4]

Mixed-discipline design teams formulate synthesis maps to develop a shared understanding of highly complex sociotechnical problems. Synthesis maps rely on a mix of primary research and literature. Even so, the process that develops them is constructivist. This process gives visual form to abstract relationships in the world as actors construct the shared social meaning that synthesis maps represent.[5] The synthesis process recursively develops narratives that re-interpret the relations and meanings of evidence to formulate models describing the systems they represent. A socially constructed consensus of meanings and relations leads to the visual representation of each system. The maps are products of socialized synthesis. They represent choices made among multiple propositions integrated in visual narratives and system formalisms. Designers choose representations to facilitate sensemaking by the content stakeholders. These are the map users who participate in the problem domain in a social system.

3 Ernst von Glasersfeld, *Radical Constructivism: A Way of Knowing and Learning* (Bristol, PA: Falmer Press, 1995).

4 Edward R. Tufte, *Visual Explanations: Images and Quantities, Evidence and Narrative* (Cheshire: Graphics Press, 1997), 9.

5 Ranulph Glanville, "Construction and Design," *Constructivist Foundations* 1, no. 3 (2006): 61–68, available at http://www.asc-cybernetics.org/systems_papers/construction%20and%20design.pdf; Charlotte Hua Liu and Robert Matthews, "Vygotsky's Philosophy: Constructivism and Its Criticisms Examined," *International Education Journal* 6, no. 3 (2005): 386–99, available at https://files.eric.ed.gov/fulltext/EJ854992.pdf.

Differentiation of Synthesis Maps

We present a framework and pedagogy from two graduate programs at Toronto's OCAD University that teach and practice system design mapping for complex social systems.[6] Based on Sevaldson's Gigamap technique,[7] the OCADU method differs in its alignment to systemic design theory and its application to integrating evidence and stakeholder perspectives.[8] Course teams produce high-quality synthesis maps using a mix of designerly concepts and formal systems models. In these courses, we changed the design-led orientation of the Sevaldson technique to a set of foundational systems thinking methods with which no student typically has prior expertise. This emphasis permits us to evaluate course maps on systemic problem reasoning and social system design. In this way, we offset a frequent bias toward visual skill or design competency.

We developed synthesis mapping over several years of studio education and formative process enhancement in our Strategic Foresight and Innovation graduate program.[9] This program adapted the Gigamap process over a two-year period, following a collaboration with Birger Sevaldson. Sevaldson developed the Gigamap approach in a decade of work with a graduate program in systems-oriented design.[10]

We co-teach courses using mixed studio and seminar pedagogy with two small team projects. Unlike Sevaldson's Gigamap studio process, the Strategic Foresight and Innovation program does not have sponsored studios. Course participants develop system maps for projects that students choose themselves. Only a small proportion of students in the transdisciplinary OCAD program have backgrounds in visual design or even other design fields. These constraints, as well as relatively short course durations, limit the extent to which students can create synthesis maps as a rich design space that addresses the complex context of real-world situations. Many course maps are led as evidence-based proposals rather than stakeholder-informed representations.

Given differences in purpose and pedagogy, the first cohorts (2011-2013) followed Sevaldson's method as closely as feasible to develop Gigamaps for social systems problems such as urban transportation, citywide infectious disease management, urban-rural wild ecosystem management, and childhood obesity. Teams typically consisted of four mixed-discipline graduate students who selected their own project team sharing a mutual interest in a wicked problem topic. Teams constructed maps over six week periods.

Since then, over ten subsequent cohorts – including the recent Design for Health program – have used an adapted method that accounts for transdisciplinary educational objectives; a shorter, half-term project; and the relationship to concurrent courses that also demand intensive team projects. We developed the synthesis map method due to these constraints and requirements as much as from a separate systems methodology. The Strategic Foresight and Innovation MDes program promotes the integration of learning across disciplines using an engaged learning process to address complex problems with societal benefit. As noted, fewer than half the students in the cohort studied design disciplines prior to enrolling in the program. As a result, synthesis maps have developed in a different direction, evidence-based and problem-centered rather than design-led.

System formalisms have become an essential bridge that enable students to develop basic skills in systemic reasoning through complex applications with a visually informed design method. The synthesis map approach combines the pedagogical value of a collaborative visual artifact to capture and represent team learning from research with the reasoning practices of systems thinking applied to complex social or policy contexts.

The synthesis map differs from the Gigamap by process more than form, as

6 Strategic Foresight and Innovation and Design for Health.

7 Sevaldson, "GIGA-Mapping."

8 Peter H. Jones, "Systemic Design Principles for Complex Social Systems," in *Social Systems and Design*, ed. Gary Metcalf (Tokyo: Springer Japan, 2014), 91–128, DOI: https://doi.org/10.1007/978-4-431-54478-4_4.

9 The OCAD University program curriculum and history are available at https://www.ocadu.ca/academics/graduate-studies/strategic-foresight-and-innovation.htm.

10 Sevaldson's program and project portfolios are described online at http://www.systemsorienteddesign.net.

both processes lead to similar map outcomes. We summarize key process distinctions in Table 1.

Table 1. Pedagogy distinctions between Gigamaps and synthesis maps.

Process	Gigamap	Synthesis Map
Course structure	14–16 weeks	6–7 weeks
Project types	Stakeholder sponsored projects	Student interest projects
Course process model	Full studio teams	Seminar with studio tutorials
Stakeholder involvement	Stakeholders in extended team	Final maps shared with stakeholders
Resources	Sponsored projects	Student-defined projects
Artifacts	Gigamap, design proposals	Synthesis map, research report
Skills training	System mapping, domain research, custom techniques, systemic relations	Systems thinking/reasoning, formal models, visual narrative construction
Assessment	Critique, sponsor adoption	Critique, course criteria

Synthesis maps generally seek to illuminate design understanding and inform proposals reflected in the visual narrative. They do not necessarily result in net new knowledge as is an aim of Gigamaps. Both mapping approaches engage the whole design team, they are communicative artifacts external to the team, but a part of the design research process.

Constructing a System Narrative

Complex societies are the typical social structure of the modern world. Interconnected, entrenched policy problems and organizational challenges confront our world as the kinds of issues we describe as wicked problems or continuous critical problems.[11] Over the past decade, design education has begun to develop new practices that respond to these types of challenges. In the context of professional practice, we also find a significant demand for transdisciplinary collaboration to address increasing complexity in healthcare, public policy, and technological systems. These developments lead to an increasing demand for visualization artifacts that facilitate sensemaking from multiple perspectives for design and decision making. These artifacts communicate the diverse perspectives and evolving design opportunities in complex social systems.

Bruno Latour notably observed that design, as a field, is changing its orientation. In the past, design focused on matters of fact – objects and their uses. Now, argues Latour, the design field focuses on matters of concern that deal with problematic, value-driven challenges such as climate change, education, and our relationship to technology.[12] Synthesis maps provide a context for systemic design activity. They allow designers to visualize large-scale, part-whole structures and networks we refer to as systems.

The system we construct in a synthesis map is not a thing existing in the world. It is a model of processes and structures of organizations and actors, which we construct by agreement in language. The system that we map becomes tangible through continuing cycles of conversation, creating a consensual linguistic domain that continues beyond the map. We recognize the map as a valid representation when both the design research team and experts in the field agree that the map is adequate. The synthesis map translates problematics or concerns determined as

11 Hasan Özbekhan, *The Predicament of Mankind: Quest for Structured Responses to Growing World-Wide Complexities and Uncertainties: A Proposal* (New York: Club of Rome, 1969).

12 Bruno Latour, "A Cautious Prometheus? A Few Steps toward a Philosophy of Design (with Special Attention to Peter Sloterdijk)," in *Networks of Design: Proceedings of the 2008 Annual International Conference of the Design History Society*, ed. Jonathan Glynne, Fiona Hackney, and Viv Minton (Boca Raton: Universal-Publishers, 2009), 2–10.

13 Charles W. Churchman, *The Design of Inquiring Systems: Basic Concepts of Systems and Organization* (New York: Basic Books, 1971).

14 Glanville, "Construction and Design," 65.

15 Marshal McLuhan, *Understanding Media: The Extensions of Man* (1964; Cambridge, MA: MIT Press, 1994).

salient from our interpretation of evidence and from stakeholder representations. The agreement emerging in the co-creation process gives a synthesis map the capacity to transcend the multiple and divergent perspectives that often appear to conflict in transdisciplinary collaboration. The iterations of design research lead to consensus – a type of qualitative saturation of the data. Additional inclusions detract from understanding rather than facilitating it. Iterative and cyclic forms of sensemaking emerge over time. These suggest the style of abductive inquiry that C. West Churchman recognized as inherent to systems thinking. Churchman called this process "sweeping in," where shared knowledge is tested and constructed in an unfolding process of iterative inquiry.[13]

Ranulph Glanville argues from a constructivist perspective that we create the concepts "from which we can conserve our objects" in the world.[14] In effect, through research and construction, we reify – rather than redesign – social systems constructed in the maps. Reification is an assimilation to the system as is, through learning about it, a process that risks creating resistance to its change. We believe that synthesis and Gigamapping circumvent the risk of reification by exploring new transformations early in the design process. And both views differ radically from the sociotechnical perspective that functionally analyzes mapped systems, as is the case with software programs.

The formal objectives of system mapping in systems engineering and analysis include the technical representation of known, planned functions within a bounded system. It also includes mapping the flow of processes and communications between objects in a reference model. System modeling criteria include completeness, accuracy, and responsible representation of a reference world. Experts from that reference world must judge the qualities of the model. Social agreement sustains constructivist objects. For the most part, this requires expert validation by participants in the system of concern. Among the criteria for successful synthesis mapping are coherence – the elements hang together – and salience or significance of problematic concerns. In a successful map, stakeholders do not perceive the system in the synthesis map as "constructed." They tend to view the system narrative as self-evident.

Similar to McLuhan's notion of hot and cool media,[15] synthesis maps can be designed in several ways. Some foreground an expressive narrative. These are similar to hot media, such as films, that demand attention to an overt message. Others entail recessive narratives, often in denser maps with deeper internal complexity. These require individual comprehension in the way that cool media, such as novels, require participation. Student projects often express a compelling central idea with formidable graphic emphasis. Constructing visual narratives is one goal of studio design training. System narratives often take the form of explicit stories represented in text and images. Framing devices structure these narratives using the rhetoric of titles and labels, signposted by steps or embedded journeys. They often select personas to embody and represent a defined series of interactions. Designers can also construct narratives through symbolism and multiple perspectives that enable a viewer to form an emergent perspective by participating with the information.

Synthesis Map Pedagogy

In our Systemic Design course projects, we find a high degree of disciplinary variety across a twenty-student cohort. The mix of students from backgrounds in business, the social sciences, the arts, and the natural sciences enables new intersections of problem frames and interventions. The course teaches general systems theory, analysis, and a range of systems thinking models and techniques in the first half of the term, and social systems theory, systemic design, and synthesis maps in the second half.

To actively integrate learning across courses, we pair the Systemic Design course with another course during the same term. Outcomes and learning endure well beyond the course when student teams maintain problem topics and team members between courses, much like a single course with multiple assignments. In a curricular relationship with the research methods course, teams construct synthesis maps from primary evidence. In the research course, maps can explain social systems and research findings, and propose design interventions discovered through field research exploration, ethnography, or workshops. As teams work from original field research evidence, their visual interpretations of findings in the complementary synthesis map show internal coherence to a real-world context. These accrue external validity conferred by stakeholders in the domain. With faculty investing in supplemental tutorial and advising sessions, synthesis maps approximate a continuous interactive studio process.

A half-term training in systems analysis and qualitative modeling precedes synthesis maps in the Systemic Design course. Students form small teams or pairs early in the course to learn system analysis, sketching, and a basic canon of systems thinking formalisms. Teams choose a topical project, and work through a series of tightly focused practice system models over the first half of the term. Several weeks of reading, lecture, and individual analysis precede team synthesis. This process serves the educational purpose of skill development over time before inaugurating the synthesis project. However, when systems analysis models are translated to a synthesis map, these analytical system sketches impose a determining constraint on framing and narrative construction. Students spend the first half of the term immersed in systems theory and modeling techniques, and discover the productive learning outcomes from the project they choose.

While system analysis appears to be an evaluative process of function decomposition within a problem, what people actually do in analysis reveals a design practice. We do not assign problems to students. They work in pairs or teams on an issue of meaningful interest that they select. Starting from a broad scope, a series of iterative inquiries leads to a well-framed question that might emerge over a period of one to three weeks in the course. The context of the inquiry emerges as students iterate a series of proposals that they present in storyboards or paper sketches. These define the boundaries of a problem situation. As in a product or interaction design process, teams work through multiple iterations of framing and sketching system relationships before team members and faculty agree that a fruitful analysis is complete.

Figure 1 A student team sketches an early-stage map to describe factors in childhood obesity. Copyright © 2012 Peter Jones.

Systemic analysis typically starts from a tightly bounded, focused problem. Examples of such issues might be an individual decision process or healthy habit formation related to a public health issue. The translation from analysis to synthesis engages a different reasoning process. It might require combining many decisions composing a complex issue such as palliative care, or synthesizing habit formation in the context of career development. The framing and boundary formation of an appropriate challenge scale emerges as a significant instructor intervention in the studio practice (Figure 1).

16 Pupul Bisht et al., "Is It Time to Pull the Plug? The Social System of Internet Hyperconnectivity" (course report, *Understanding Systems & Systemic Design*, OCAD University, Toronto, 2017).

17 Ibid., 18.

Course-Based Synthesis Map Case

Figure 2 shows a course map titled *Hyperconnectivity*.[16] This is an example of a strong narrative with implicit detail developed through extensive collaborative inquiry. Hyperconnectivity incorporates several system formalisms. The team had selected each of these to address a numbered stage of inquiry within the visual metaphor of a plugged-in brain. Team members largely interpret and infer these visual arguments from published evidence. The project did not involve external design research or access to stakeholders.

The map expresses a narrative drawn from a continuous dialogue among students and faculty. In synthesis mapping, a problem frame will typically shift several times during the course of inquiry. The team initially focused on the changing media ecosystem of film production and online media consumption, with an emphasis on technological disruption. The need to map social complexity rather than technology development redirected the team's initial frame activity. Early maps were sketched on paper by hand. These maps traced the stages of media system movement from film to television, online, and mobile. They charted such key technological drivers as video on demand. The team also focused initially on the Netflix platform as a source of technologically-determined user habituation, modeling a vicious circle loop. As the project developed through studio discussions, tutorials, and continuous mapping, the team resolved the problem frame to "exploitation of internet addiction."

Working with a series of systems models while engaging in research led students to map several levels of causal effects. The map indicates these with context numbered 1–4 across the main image as part of a full visual narrative. In the associated course report, students described the dynamics of the map (Figure 3) in this way:

> "Many of the relationships were fairly clear, from increasing time on devices to rise in social isolation to decreasing civic engagement and increasing mental health issues. Decreasing empathy due to less face-to-face time, increasing conflict because of lack of empathy, and a potential rise in violence are all shown on our implications map and causal loop diagrams. Most of the benefits were connected to generation of profit and not social or psychological well-being. We came to the conclusion that the potential of hyperconnectivity to create social issues was part and parcel of the reality of an increasingly established and quickly spreading social norm."[17]

The team developed the hyperconnectivity narrative through a systemic inquiry. They represented this materially by hand sketches that they evaluated in studio dialogue. The map synthesis process took these steps: 1) identifying the arena of interest, 2) identifying the wicked problem, 3) boundary formation, 4) stakeholder analysis, 5) value analysis, 6) causal system analysis, 7) researching the arena, 8) locating issues in micro and macro scales, 9) iteration, and 10) finding implications.

The original frame of the problem in this synthesis map was "on-demand media consumption." During synthesis, the team reframed this problem as "Internet addiction in an age of overly (hyper) connected consumption." Several system models explained media and consumption from the perspectives of organizations and processes, as well as accounting for individual perspectives and causality. They selected visual formalisms as appropriate mapping tools for the problem in response to questions that emerged in the inquiry. Each encapsulates a type of systemic reasoning. Because these models are canonical and easily explainable, they aid the knowledge translation process with stakeholders as well as developing system thinking skill. The sequential narrative was not ordered from system analysis, but rather defined for communicative impact.

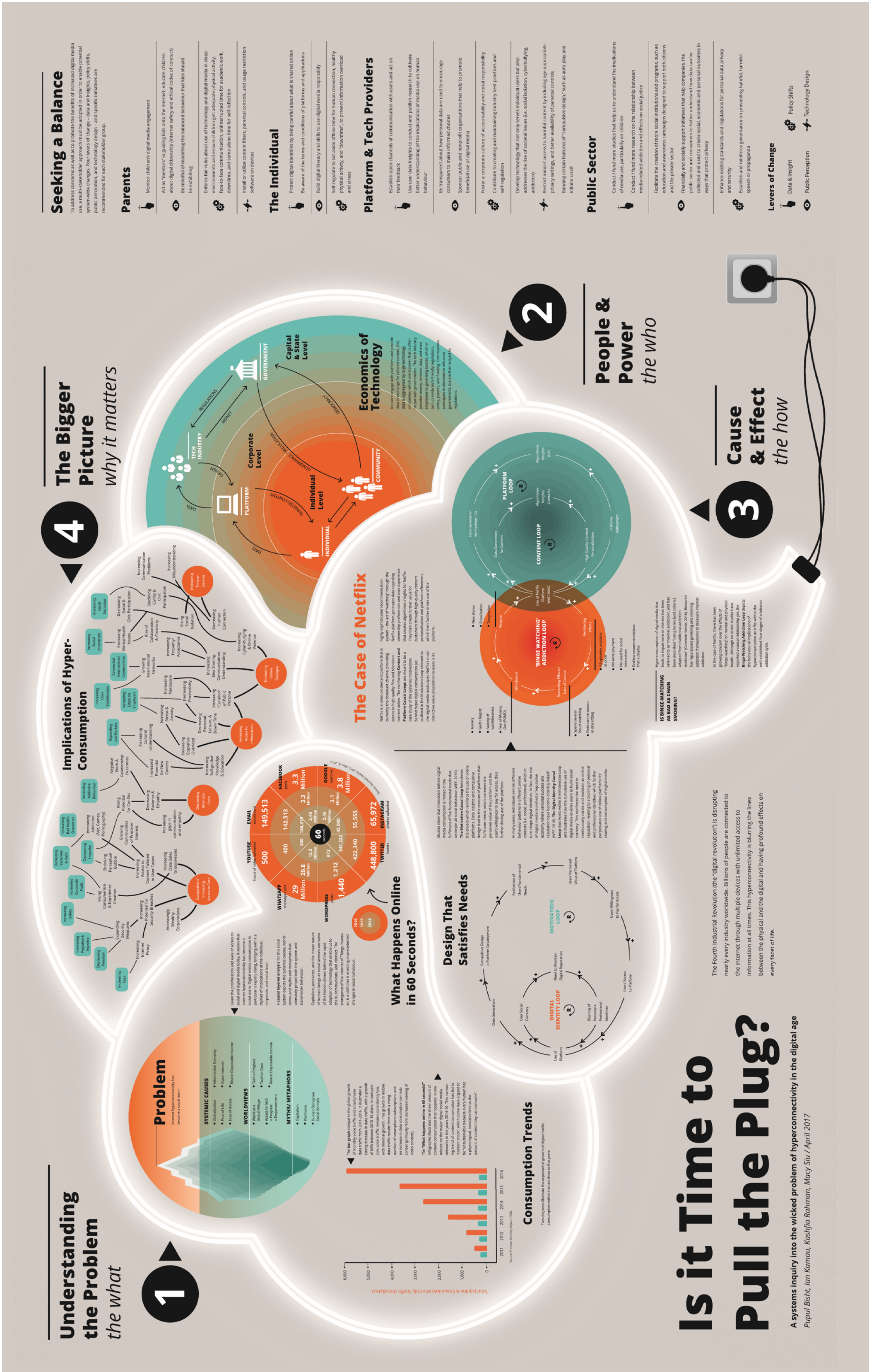


Figure 2 “Is It Time to Pull the Plug? The Social System of Internet Hyperconnectivity.” Image reprinted with permission from Pupul Bisht et al.

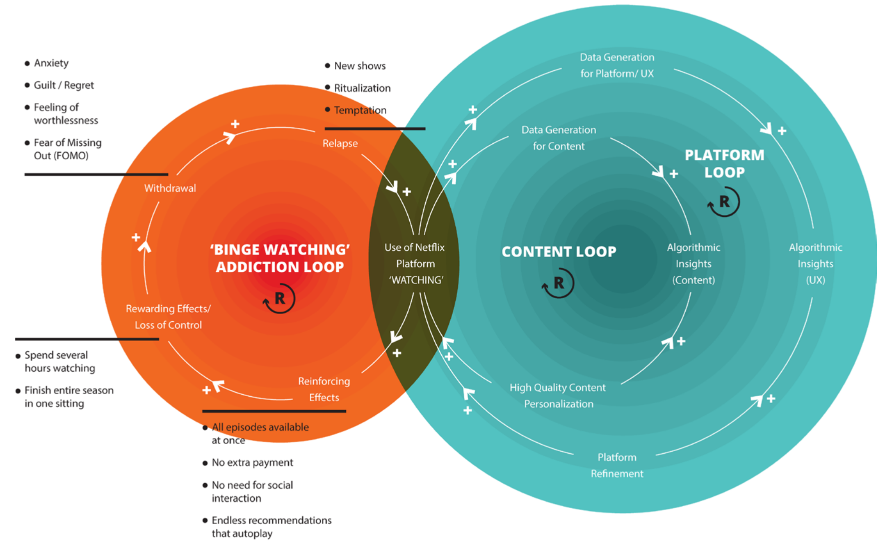


Figure 3 Inset from "Is It Time to Pull the Plug? The Social System of Internet Hyperconnectivity." Image reprinted with permission from Pupul Bisht et al.

The Hyperconnectivity synthesis map (Figure 2) contains several types of models. Each type of model is associated with a developmental issue or question.

1. **Understanding the problem**. A causal layered analysis[18] depicts problem frames in a layering of stages of understanding. The map depicts the visual form of these layers. These forms often resemble the layers in an iceberg metaphor. We designate the top-down stages of layers as 1) The litany, isolated problems perceived as presented; 2) social causes, typical of policy proposals; 3) cultural and collective worldviews; and 4) myths and metaphors, deep unreflective narratives that might guide values without awareness of the source. The model in the map reveals a set of layers under the social norm of Internet connectedness. The deeper layers enable framing of relevant aspects at each level, providing a composite view of the problem as a social system of beliefs and values.

The causal layered analysis model frames the concerns of addiction and social health. This lends insight into the severity of the larger wicked problem of Internet addiction, hyperconnectivity, and resulting consumption. An inset, shown as a radial diagram, represents the visual snapshot of the sheer traffic volume of online media during a sixty second period.

2. **Stakeholders – People and Power**. The map represents the multilevel, nested social system using a systemigram.[19] This is a well-known modeling formalism used to represent organizations and networks, with connected relations between people and system levels including platforms, industries, and government.
3. **Causality**. Figure 3 shows an inset from the map that employs causal loop diagrams.[20] These diagrams represent the discovered functions of the relation between the individual "addiction loop" (orange) and the media system functions (blue). The (R) indicates the reinforcing loop system (increasing effects) and the (+) indicates a reinforcing loop.
4. **Implications**. Here, the team chose an influence map[21] to represent the spreading relations from problems in the social system. These move from root issues (orange) to outcomes and symptoms (blue).

The synthesis map in Figure 2 joins multiple layers and timeframes to show a rich picture of growth. This interprets the "threads of value exchange" from individual to state. A causal loop diagram highlights the causal relation between individual

18 Sohail Inayatullah, "Causal Layered Analysis: Poststructuralism as Method," *Futures* 30, no. 8 (1998): 815–29, DOI: https://doi.org/10.1016/S0016-3287(98)00086-X.

19 Charles D. Blair, John T. Boardman, and Brian J. Sauser, "Communicating Strategic Intent with Systemigrams: Application to the Network-Enabled Challenge," *Systems Engineering* 10, no. 4 (2007): 309–22, DOI: https://doi.org/10.1002/sys.20079.

20 Peter Senge is perhaps the best-known author to advocate the use of causal loop diagrams, in the *Fifth Discipline* management series. Based on MIT system dynamics modeling, causal loop diagrams visually capture problematic relationships, known as archetypes, which are portrayed as regularities using the formalism. Peter M. Senge, *Catalyzing Systems Thinking within Organizations* (Cambridge, MA: System Dynamics Group, Sloan School of Management, MIT, 1987).

21 The work of John Morecroft represents a foundational approach to influence mapping. The line digraph influence map can follow different logical forms, such as structural influence and reachability. See John D. W. Morecroft, "System Dynamics and Microworlds for Policymakers," *European Journal of Operational Research* 35, no. 3 (1988): 301–20, DOI: https://doi.org/10.1016/0377-2217(88)90221-4.

identity and motivation. The map links media consumption to human behavioral needs through the case of the Netflix service.

A larger graphic metaphor – the image of the brain as a visual organizer – helps to portray the levels of information. These move from core to periphery, revealing the variety of visual models, causal loops, influence diagrams, and layered analysis integrated in the synthesis map. Multiple embedded causal loops narrate the dynamics of each system and the transitions in each. The central image of a brain as "plugged-in" emerges as a visual organizer portraying the levels of information from core to periphery. This metaphor integrates the various layers of systemic information, visual models, statistical data, and research data.

We suggest the synthesis map functions as a stakeholder instrument that enables people to narrate and identify points of intervention and approaches to change. It also allows them to explore and recommend strategies to mitigate and temper problematic symptoms and outcomes.

Process and Framework

Synthesis maps evolved from earlier techniques in systemics and design methods as a process for constructing and communicating the shared narratives implicit in complex sociotechnical systems. Similar to Gigamaps, but unlike infographics, they intentionally communicate the complexity inherent in systems. The optimize representations through design synthesis to balance this objective with narrative clarity. In this way, synthesis maps are more than system models or infographic simplifications of complex scenarios. They follow systemic principles to disclose and critique the entanglements of the complex problem that they reveal. They afford the awareness of options within the lived reality of a system, and allow stakeholders and designers to consider the future evolution of the system.

We consider synthesis maps to be heuristic and developmental. Given the course objectives and context, these maps are evidence-based reflections rather than radical design proposals. They aim to reveal the emergent consequences of intervening in complexity. While course projects can tend toward simplistic trajectories or solutionism, critiques aim to redirect proposals toward viable, sustainable interventions in which stakeholders might recognize value. Sevaldson first cautioned against the urge to sacrifice necessary depth in simplifying a system in order to promote a preferred narrative to stakeholders.[22] We have discovered that significant learning occurs in the conversations that emerge naturally when constructing synthesis maps. We believe the shared mental model developed in the mapping process enables stakeholders to flexibly navigate and reframe issues and potentials in the "real" system represented in the map.

The continued learning in the systems pedagogy associated with Gigamapping and synthesis maps leads to an emergent original canon of systemic modeling and design techniques. Sevaldson recently catalogued an extensive array of systemic relations identified in analysis and inscribed by various line forms.[23] These define a visual language that enables practitioners to envision and reference these relationships. This expansion of relational variety improves the fit of maps to world. This provides new reference models that better describe the inherent complexity of interpersonal and emotional relationships, structural, organizational, and temporal relations, valence and persistence, and so on. Such models are valuable for both precautionary and imaginary intentions. In the clinical cancer case we discuss later, a legend shows the variety of structural relations in the cancer system. Yet these relational trajectories do not even begin to model the inherent human and social complexity in the field of cancer practice and within patient experience.

System maps are not a new graphic design form. Papanek's influence maps

22 Sevaldson, "Systems Oriented Design," 1–22.

23 Birger Sevaldson, "A Library of Systemic Relations" (presentation, RSD5 Symposium 2016: Systemic Design for Social Complexity, October 13–15, 2016, OCAD University, Toronto, Canada), available at http://openresearch.ocadu.ca/id/eprint/1929/.

24 Victor J. Papanek, *Design for the Real World*, 2nd ed. (Chicago: Academy Chicago Publishers, 1984). An image of the book's map set is available at http://www.core77.com/posts/19112/Competition-Design-for-the-Real-World-REDUX.

25 Hugh Dubberly was editor of the "On Modeling" column in ACM *interactions* for several years, and his collections remain available at http://dubberly.com/models.

26 The NID Product Design program is uniquely situated in India and globally for its socially relevant focus and wide range of integrated disciplines. For more information, see http://www.nid.edu/education/master-design/product-design/p-overview.html.

27 M. P. Ranjan, "Creating the Unknowable: Designing the Future in Education," in *Proceedings of the 6th International Conference of the European Academy of Design* (Bremen University, 2005), 29–31.

28 By "stakeholders" we mean in nearly all cases those participants in the operational context of a domain being mapped whose careers and commitments are invested in the outcomes of proposed processes and interventions.

remain resonant after fifty years.[24] But transdisciplinary translations between systemics and design appear to be a recent project. Hugh Dubberly's open access work over the last decade[25] is informed by Dubberly's collaborations with cyberneticist Paul Pangaro and others. They offer exemplars of applied system models for a variety of design contexts. These exemplars and approaches have been accessible for years. Yet while many design schools teach mapping for visual communications, and a few offer systems thinking, few graduate programs currently lead Gigamap courses. India's National Institute of Design Product Design program[26] has developed a robust curriculum and organic approach to Gigamap pedagogy, continuing the tradition of socially-progressive systems design established by program founder M.P. Ranjan.[27]

The movement toward visualizing complexity, large social systems, and multiple perspectives has led to interest and demand from complex sectors such as healthcare and public policy for visual scenarios that express critical problematics from the stakeholders' perspective.[28] When stakeholders are part of the design team, they experience collective learning and organizational value in the discursive process of formative map-making. This goes well beyond the ostensible value of the final map artifacts. Team members involved in a systemic inquiry – and typically leading field studies or action research – engage in a collaborative learning process over the period of the design study. They activate concept development, they frame and reframe problems, they consider change proposals, and they form collective mental models across organizations.

A mapping project can embrace multiple purposes. The first of these involves researching, understanding, and communicating the social system problem area. Another purpose is to effectively identify cycles and processes in social systems that might represent productive areas for intervention or system and service design. Course-based synthesis maps do not usually venture into system redesign, as students typically create maps without the benefit of system stakeholders on the team. The necessity of stakeholder inclusion becomes clear when student projects attempt to propose intervention and design changes without their input. Course projects often describe first steps toward future redesign proposals based on principles and analysis, and – where possible – a deep understanding of the problem domain.

Synthesis Map Methodology

Through six years of progressive improvement in studio and teaching practices, sponsored design research, and reflective practice, the systemic design community developed a generalized process for synthesis mapping. It may be premature to propose a formal method for design-led systems mapping. We have developed the method as an exploratory, constructivist process that adapts well to the unique requirements of a context, sponsors, and design teams. Therefore, adaptations from learning always emerge in each course or major project. Many of these adaptations remain tacit and are not published, but sponsored projects are yielding process data as well as knowledge translation, enabling process reflection through feedback.

A general sequence of synthesis mapping activities consists of five stages:

1. Scoping and framing, supported by inquiry with domain research and literature research.
2. Visual analysis and problem development, from multiple sources or human research, employing system sketching and visual note taking.
3. Initial knowledge synthesis, through preliminary map sketching.
4. Engagement, critique, and evolution of maps into complete visual system narratives.
5. Final map design, visualization, and review iterations.

A methodological frame requires an integrated set of related methods that are valid within an epistemology or framework. These must be published or used in a discourse community. A methodological frame provides guidelines for effectively adapting methods for different contexts. Synthesis map methods share the epistemological perspective of constructivist pragmatism. They also share the methodological context of design research with Gigamaps and other systemic design approaches.

Synthesis mapping does not lend itself to a definitive canon of methods. Most educators present the process of mapping as an expansive learning context for complex design problems, and not as a range of research methods. Rather than making methodological claims, we can articulate the OCADU practices shared among these programs. These practices enable effective performance in collaborative team mapping for framing and design intervention. We propose them as guidelines for comparing methods and we put them forward to facilitate further development.

Design Guidelines

Over the course of studio practice, we have identified essential methods as design guidelines that others may learn and replicate across courses and contexts. This is a notional checklist, rather than steps, to guide a comprehensive synthesis map project.

1. **Problem Selection**. We initiate synthesis maps as projects based on a complex problem topic of authentic concern to a team. The selection of the initial topic serves as an attractor for team participants with an affinity for the problem area. These topics often involve wicked problems. One key principle is that the initial problem framing will change with design research, often significantly. Project teams must allow this possibility to avoid the risk of forcing a narrative to fit a preconceived system.
2. **Stakeholder Access**. In a studio process, teams conduct and aggregate appropriate research. They perform analyses, summarize knowledge, and proceed with stages of system sketching. Teams can proceed with or without access to informants and stakeholders. Nevertheless, stakeholder feedback significantly aids the realism and applicability of findings and proposals.
3. **Stakeholder Discovery**. Mapping teams conduct iterations of stakeholder identification and discovery to identify the actors in the social system that they map. Depending on the variety to be resolved in the problem domain, teams can evaluate stakeholders for their fit across multiple categories. Teams must identify typically affected stakeholders, such as primary (direct), indirect, and vulnerable. Structural categories include jurisdiction, institution, social and community, and ecological stakeholders. Ontological stakeholders can be selected from models of belief and worldview. Diversity can be selected from age, ethnicity, and geography. Expertise and relevant professions can be of interest.
4. **Research Question**. In coursework, the synthesis map project is best linked to a research-based course that affords access to stakeholders and participants for interviews, observations, experts, and rigorous inquiry into the problem domain. A research question or problem statement drives the synthesis process in these cases. A research question helps define the project scope and system boundaries of the social system or service.
5. **Inquiring Systems**. Teams use several modes of inquiry – inquiring systems[29] – in the course exercises and they adopt these as methods in the mapping process. They typically clarify system purpose and contexts as an emergent process in successive mapping iterations. Gharajedaghi's

29 Churchman, *The Design of Inquiring Systems.*

well-known technique of iterative inquiry[30] is taught in the course, and is often used as a common starting point for unpacking subsystems into functions, structures and process relationships, and defining the appropriate boundary for the map project.

6. **Modeling**. We introduce a basic set of preferred system formalisms to propose and construct system behaviors that represent problematic structures and regularities in a social system. We use systemigrams, causal loop diagrams, problematiques,[31] influence maps,[32] rich pictures,[33] iterative inquiry, process flows, panarchy,[34] foresight-based system models,[35] and others to represent specific and appropriate system relationships.
7. **Representations**. We encourage teams to organically explore original ideas and visually represent the salient, significant aspects of a social system. Teams can use stakeholder tables, organizational breakdowns, architectural maps, structural and process views to represent wholes and parts in relation to each other.
8. **Interpretations**. Students are not always able to find appropriate experts who can assess their hypotheses. In coursework and research, they use visual reasoning and mental simulations to evaluate the fitness of concepts and system proposals. Visual representations are interpretations, and teams compose them using an abductive process. They propose a hypothesis in a system, they conceptually test proposed processes that explain observed behaviors, and they re-represent the process. Dozens of interpretive reasoning cycles occur in any mapping process.
9. **Visualization**. Teams perform complete map visualization including the choice of integrating theme, palette, visual metaphors, and narrative tropes close to the point of finishing a version of the map. Teams sketch visual metaphors and assess them for their fit to the domain and stakeholder values. They test narrative proposals against the map and identify gaps in the narrative or process flows.
10. **Intentionality**. Systemic problems are inherently complex. First order outcomes and goals may have problematic, second order consequences. The ultimate intention or outcome of a system map may be uncertain and it may not always be possible to define. While some synthesis maps identify interventions early in the design process, they more often require a shared understanding and narrative before defining options for systemic design intervention and change proposals.

We draw these design guidelines from reflective practice and from the guidelines that we provide to student teams. They are the outcomes of collaborative learning in studio work between faculty and students. They do not comprise a complete methodological framework. We would welcome other guidelines and methods that lead to an inclusive framework that might incorporate practice-based learning from other systemic mapping methods.

Integration of Visual Formalisms

Systems thinking disciplines have produced a variety of visual models to define operational models of systems and their relationships as an aid in understanding complex systems. We refer to these models as formalisms because they provide a syntax for expressing the functions and actions in the types of systems that permit well-codified description. Systems thinking disciplines that developed formal models for over 50 years as methods of systems analysis and problem structuring. Despite this rich history, design research and traditional infographics rarely use them. As widely understood conventions in system reasoning, visual formalisms

30 Jamshid Gharajedaghi, *Systems Thinking: Managing Chaos and Complexity: A Platform for Designing Business Architecture*, 3rd ed. (Morgan Kaufmann, 2011).

31 John N. Warfield and George H. Perino Jr., "The Problematique: Evolution of an Idea," *Systems Research and Behavioral Science* 16, no. 3 (1999): 221, DOI: https://doi.org/10.1002/(SICI)1099-1743(199905/06)16:3<221::AID-SRES245>3.0.CO;2-G.

32 Morecroft, "System Dynamics and Microworlds for Policymakers."

33 Peter B. Checkland, "Soft Systems Methodology," *Human Systems Management* 8, no. 4 (1989): 273–89, DOI: https://doi.org/10.3233/HSM-1989-8405.

34 Lance H. Gunderson and C.S. Holling, *Panarchy: Understanding Transformations in Systems of Humans and Nature* (Island Press, 2002).

35 Andrew Curry and Anthony Hodgson, "Seeing in Multiple Horizons: Connecting Futures to Strategy," *Journal of Futures Studies* 13, no. 1 (2008): 1–20.

can facilitate communication and problem discovery with conversant stakeholders. They are difficult to use as design techniques due to rigid, formal notations, and analytical forms that may impose arbitrary limits on the conceptual development of a map.

Formalisms are modeling techniques employed in systems engineering to precisely describe system functions. The denotation of a "formalism" implies a relationship to mathematical or programmatic representation, such as so-called "hard" systems developed visual modeling to portray dynamic relationships that could be modeled mathematically. Visual formalisms also convey epistemological frames associated with the model. These carry certain assumptions and a style of argument based on the reference data.

Following the foundational Jackson typology of three schools of systems thinking in operations research,[36] visual formalisms are typical methods in the hard systems traditions, primarily system dynamics and systems engineering. So-called "soft" systems[37] approaches are interpretive, emphasizing the constructive nature of systems as conceptual formations, adopting the use of rich pictures and conceptual models for mapping processes and actors. Much less attention has been paid to visualizing emancipatory or critical systems, perhaps because its practices have been developed for dialogue and engagement as opposed to analysis.

Unlike formal systems methods that require training or experience to comprehend, synthesis maps communicate the narratives and concerns identified within a system to different stakeholders who did not participate in the mapping design research. The exemplar maps in this article show composites of multiple visual formalisms. They convey arguments of causality or proposals for system change over time. An unusual and deliberate combination of rich picture, system dynamics, and critical change arguments can be found in many synthesis maps. The visual explanations have independent meaning, but they are joined to support a coherent total narrative.

Figure 4 presents a synthesis map[38]designed and published by OCADU's Strategic Innovation Lab (sLab) for the Digital Era Governance project, a SSHRC[39] research initiative on the changing dynamics of Canadian governance in the era of digital citizenship and online government services. A series of workshops and collaborative reviews formulated near-future scenarios as system models emerging from multiple conditions of change in Canadian governance. The map incorporates a combination of three influence diagrams as visual arguments within a rich picture synthesis map based on a representation from the Three Horizons[40] critical systems and foresight method.

Many synthesis maps are envisioned using timelines or formed with definitive temporal models over different time periods, or horizons. Long horizon system models such as in Digital Era Governance integrate anticipatory reasoning in the form of foresight models, presented as an integrated rich picture.

This map was constructed in multiple stages, with versions of the map employed in a series of three stakeholder workshops for interactive discourse and collective revision. The Three Horizons was proposed as an initial template in a first workshop, to elicit temporal change proposals envisioned at each horizon. These initial contributions had a significant effect on framing and further conceptual design. Interpretations led to the visual metaphors of "waves of change" and the tension between the first and second horizon periods, portrayed as the pressures of tectonic plates between overwhelming forces.

At three subsequent workshops, groups of twenty to thirty participants were engaged to propose concepts that advanced this model, using sticky notes or markup on a printed skeletal outline of the Three Horizons synthesis map. In a final workshop, small groups generated three influence maps revealing prospective

36 Michael C. Jackson, *Systems Methodology for the Management Sciences* (New York: Plenum Press, 1991).

37 Checkland, "Soft Systems Methodology."

38 The synthesis map was designed and produced in 2015 by an OCADU sLab research team consisting of Greg van Alstyne, Peter Jones, Kelly Kornet, Patricia Kambitsch, Peter Scott, and Goran Matic.

39 Digital Era Canadian Governance, a Partnership Development Grant funded by Social Sciences and Humanities Research Council (SSHRC).

40 Curry and Hodgson, "Seeing in Multiple Horizons."

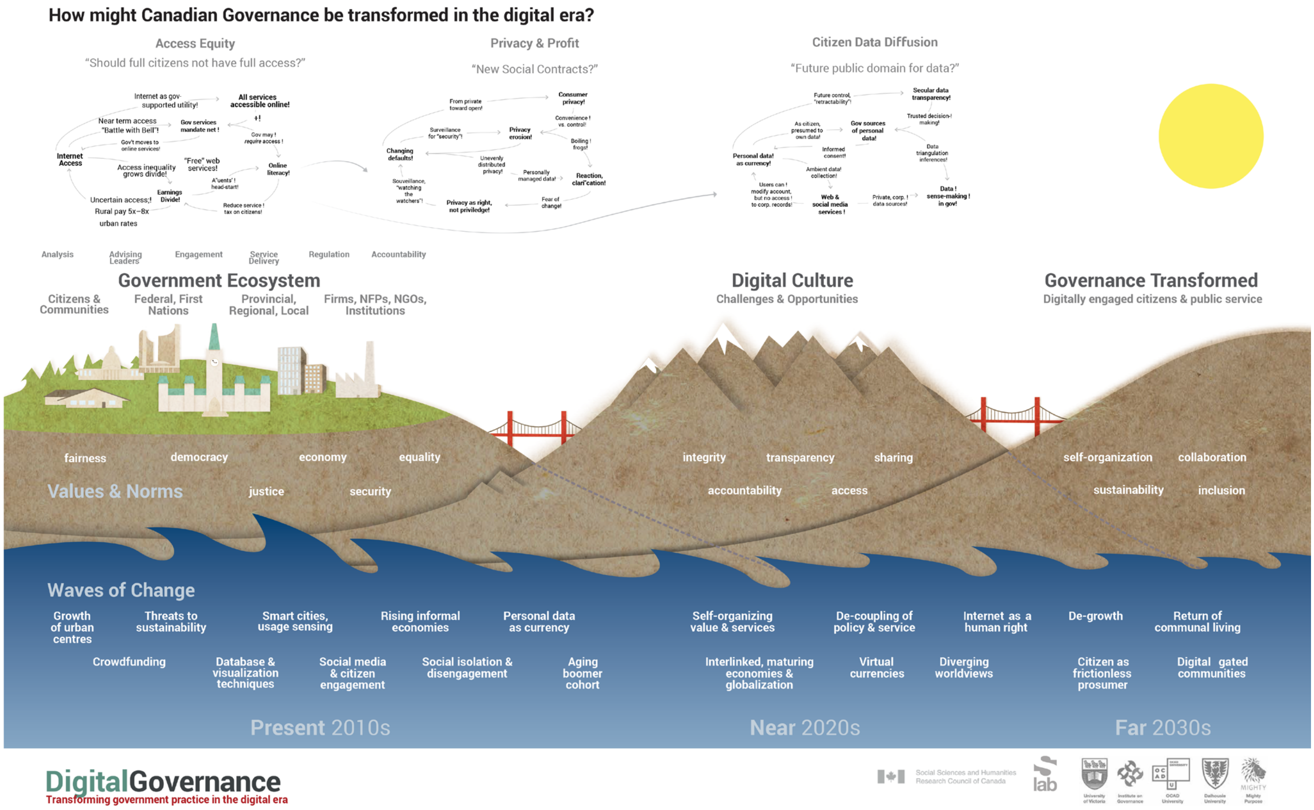


Figure 4 Digital Era Governance Synthesis Map. Copyright © 2015 Strategic Innovation Lab, OCAD University.

relationships among digital citizens and government services in a structured problematique. Figure 5 shows an inset influence map that proposes a problematique for "access equity." Access equity is the concern for future citizen access to Internet and services as government becomes "digital by default." Here the argument is made that access becomes a public good and its provision will be demanded as a utility in the future. Access equity makes the claim that current Canadian service provision is inequitable and discriminatory, and that as access is required for essential government services, government must resolve inequity through support, subsidies, or public carrier provisions.

The three influence maps (that compose a problematique[41]) are read from left to right, with temporal dependencies that propagate over the period of the horizons in the map. Leverage points in near-term issues include "Government moves to online services," "uncertain access, rurals pay 5–8 times urban rates," and "the battle with Bell." These have various influences on bolded issues, which represent foreseeable outcomes for policy intervention. Access Equity links via "online literacy" to the Privacy diagram, then to Data Diffusion over the timeframes.

Influence maps[42] are a type of hard system model, similar in modeling use to causal loop diagrams[43] such as the one displayed in Figure 3. The hard system models often function as standalone analytical patterns included within synthesis maps to describe subsystem behaviors within a social system.

The expressive power of synthesis maps can be seen in the integration of any or all modes of systemic reasoning within the same narrative. The Digital Governance map incorporates all three modes of Jackson's typology. The type of interpretive conceptual map is consistent with the soft systems approach,[44] with its interpretive and figurative rich picture, and it foregrounds the visual narrative with a critical systems approach (in the Three Horizons). Soft system methodology (SSM) endorses mapping as a process for mutual learning and collective action,

41 Warfield and Perino, "The Problematique," 221.

42 John N. Warfield and Scott M. Staley, "Structural Thinking: Organizing Complexity through Disciplined Activity," *Systems Research and Behavioral Science* 13, no. 1 (1996): 47–67.

43 Senge, *Catalyzing Systems Thinking within Organizations.*

44 Checkland, "Soft Systems Methodology."

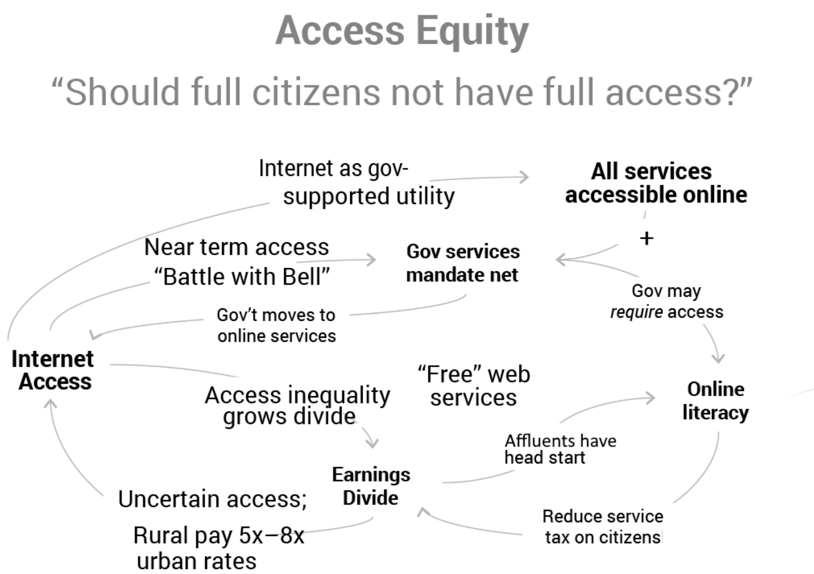


Figure 5 "Access Equity" influence map inset in synthesis map. Copyright © 2015 Strategic Innovation Lab, OCAD University.

rather than representation – an action learning approach compatible with design. A typical intention of the rich picture is to facilitate an ongoing learning through the creation of a common language with stakeholders, in text, image, and relationship.

Clinical Cancer System Case

In 2017, we reported an sLab synthesis map in a *Current Oncology* article,[45] designed in collaboration with a multi-year Canadian Institutes of Health Research (CIHR) study. Based on qualitative and national survey research, administrative data, physician and patient interviews, and cancer statistics, the CanIMPACT study investigated the efficacy and improvement of primary care in the Canadian cancer treatment system. Two synthesis maps were developed, a clinical system (Figure 6) and a patient-centered map (Figure 7). The clinical map (Cancer Care Pathways in Canadian Healthcare) was a large-scale process and system map designed to communicate findings and interventions from the CanIMPACT study. The patient map emerged later as a necessary resolution to the discovery that the patient experience was unpresentable within the clinical system perspective, based on the social construction of validity from patient stakeholders involved in the map team.

The clinical map visually represents breast (pink) and colorectal (blue) cancer processes across Canada, with differences between provincial and territorial systems inset in the baseline. A roadmap metaphor is employed throughout to show the patient flow across stages of cancer care. Road signs (green) identify clinical cancer stages across the roadmap from Pre-Diagnosis to Survivorship. Tree images associate seasonal metaphors with the clinical stages of the patient's journey.

Three levels of primary, secondary, and tertiary care stack visually across the map above the sequential stages. Information and communications technology, independent from levels and stages, was distinguished by its problematic disconnection from primary care. Clinical pathways are color-coded where experts defined differences between breast cancer (pink) and colorectal cancer (blue). White pathways indicated current practices shared across all cancer journeys.

The patient-centered map (Figure 7) was designed as a response in the study when recognizing patient experiences were merely represented as flows within the clinical perspective and could not be rendered effectively in the map. As a

45 Peter H. Jones, Smriti Shakdher, and Prateeksha Singh, "Synthesis Maps: Visual Knowledge Translation for the CanIMPACT Clinical System and Patient Cancer Journeys," *Current Oncology* 24, no. 2 (2017): 129, DOI: https://doi.org/10.3747%2Fco.24.3452.

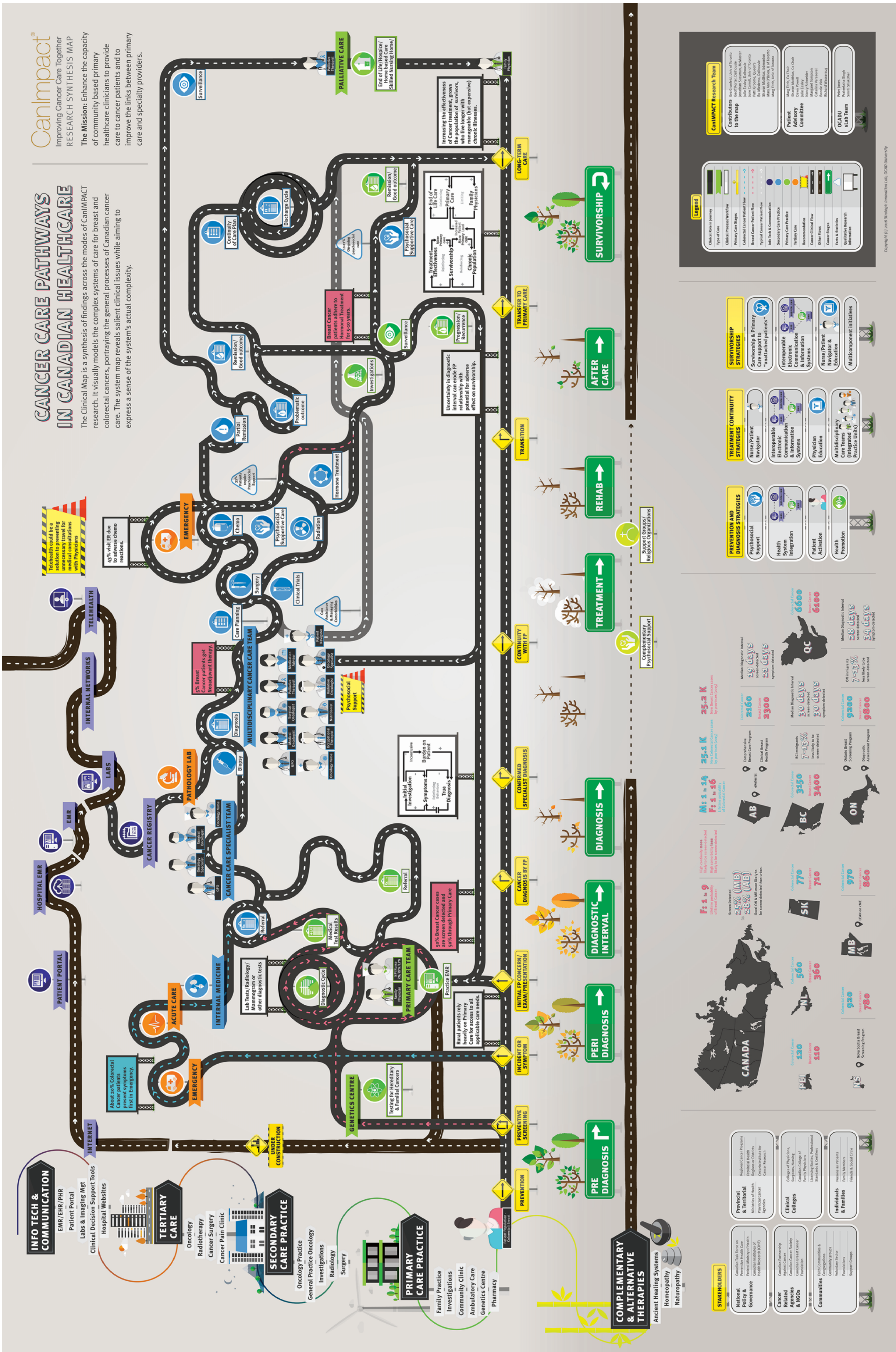
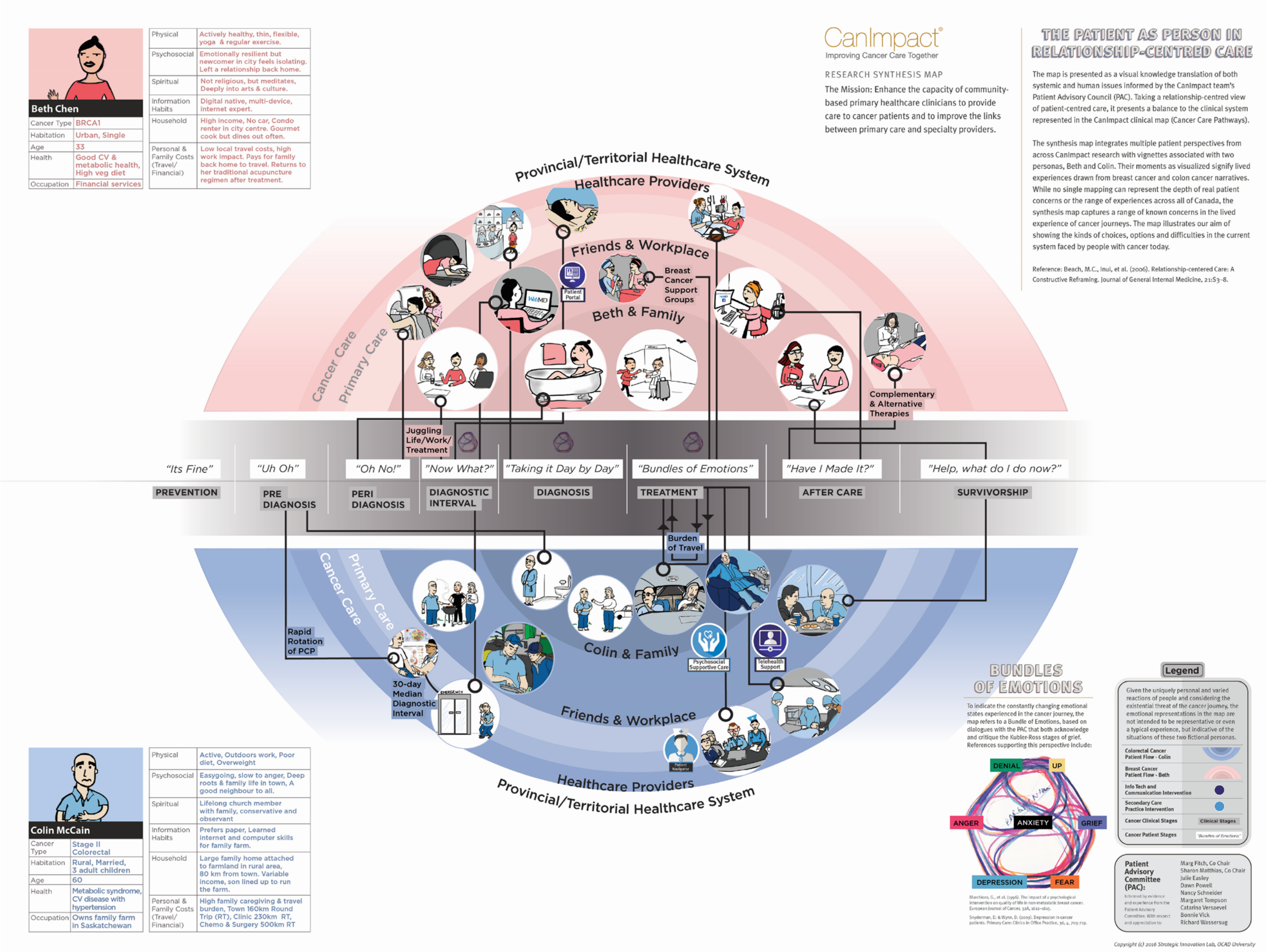


Figure 6 CanIMPACT Clinical Synthesis Map. Copyright © 2016 Strategic Innovation Lab, OCAD University.



relationship-centered care perspective, it illustrates the most concerning experiences associated with two personas of breast and colorectal cancer patients and families and maintains correspondence to actual patients in these categories. A socioecological system model[46] represents the ecology of care, where relationships in the patient's world are closer in the center and extend outward. The sequential stages of the clinical cancer journey are retained in the middle; connecting lines show how these are experienced as nonlinear.

Figure 7 CanIMPACT Patient-Centered Synthesis Map. Copyright © 2016 Strategic Innovation Lab, OCAD University.

The clinical map (Figure 6), however, represents patients in a constant flow through a system of services. While services are shown as "stationary" locations, patients represent the flows in the pathways. The design approach rendered a hand-drawn sensibility to show patients as empathic characters rather than iconic symbols as in the clinical map. This visual language choice expresses a tangible experience for actual patients, visually a kind of construct validity, as patient representatives are able to read this map unaided, without losing correspondence to the range of real states of the cancer experience.

46 Urie Bronfenbrenner, *The Ecology of Human Development: Experiments by Nature and Design* (Cambridge, MA: Harvard University Press, 1979).

Conclusion

We present a framework and process for a visual language developed as a visualization method for mapping large-scale systems. Synthesis maps integrate design constructs, research evidence, and domain knowledge to present complex visual narratives for knowledge translation, stakeholder communication, and intervention decisions. Synthesis maps formulate a shared mental model and domain language in the process of iterative artifact construction. While not a specific modeling language, such as found in traditional system modeling techniques, the synthesis map crosses genres of visual systems thinking to coherently and tangibly render research observations and design choices.

We show that current system mapping pedagogy in graduate design programs is a growing and vital transdisciplinary design process and a valuable articulation skill in demand in various contexts. The synthesis map approach privileges system formalisms as an explicit training method in service of teaching systems thinking methods for complex societal problems supported by evidence in course settings. It is explicitly constructivist, as the system being described is designed from a team's interpretation of extent research, their own research, and in and for conversation with stakeholders. A constructivist pedagogy is reinforced by the validation of design critique and socialized participation with stakeholders, allowing for feedback to shape the map until the rendered concepts are narrated and accepted within the community the models represent.

Finally, the formal models themselves are employed to support a scaffolding of systems thinking skills in the associated course, enabling rapid formulation of complex concepts in a domain. The learning objectives support the skills and conceptual learning of systemic reasoning; therefore, the scaffolds offered by formalisms become less important with practice and experience.

As with most interpretive system mapping methods, the purpose of the visual narrative is to facilitate understanding of significant actor-relationships within a system of concern to stakeholders and informed audiences. The synthesis map aims to present a rich representation of the inherent complexity in real social and design challenges, and therefore the maps are deliberately dense, multi-leveled, and often complicated. An open-ended visual modeling approach provides expanded degrees of freedom for system definition and intervention, enabling the synthesis maps to be employed in a wide variety of applications and multi-stakeholder problems. These maps have significant potential as design artifacts to explain and propose, through visual composition, emerging systemic problems and regularities as narratives entailed in complex sociotechnical systems such as in healthcare, public policy, or urban design planning.

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