SYSTEMS THINKING

A Dissertation

Presented to the Faculty of the Graduate School

of Cornell University

in Partial Fulfillment of the Requirements for the Degree of

Doctor of Philosophy

by

Derek Anthony Cabrera

May 2006

SYSTEMS THINKING

Derek Anthony Cabrera, Ph.D.

Cornell University 2006

This research set out to clarify the construct of systems thinking and to define it as a conceptual framework apart from systems science, systems theory, systems methods, and other perceived synonyms. Greater clarity in the systems thinking construct will assist any one of the many current implementation efforts in which systems thinking is being applied in both scientific disciplines and practical fields. One case of this is the application of systems thinking in public health. The challenges associated with this effort are generalizeable to any of the other fields in which systems thinking is being applied. The ambiguities of the systems thinking construct are central to the challenges people face in understanding and implementing systems thinking.

This exploratory empirical research used structured conceptualization methodology, which mixes qualitative methods with multivariate statistical methods, to investigate the challenges of implementing systems thinking in an applied context. The analysis shows that: (1) the literature reveals that significant ambiguities exist about what constitutes systems thinking and that practitioners are adopting these ambiguities, (2) the methodological review reveals that there are a disproportionate number of descriptive studies and significantly fewer empirical studies and that there are construct validity problems regarding systems thinking in the few existing empirical designs, (3) the results of statistical tests and descriptive statistics across a range of studies show that the aggregate participant sorts in this study are reliable to a high degree, (4) additional statistical tests show low significance in participant ratings and may indicate that the systems thinking construct is sufficiently vague and that

participants had difficulty differentiating between clusters with respect to importance, and (5) 25% of clusters representing 48% of the total statements have to do with learning more about systems thinking through educational initiatives, suggesting that participants are unclear about many aspects of systems thinking.

These findings suggest the need for further development and research on four fronts: theoretical, implementational, empirical, and educational. A theory of systems thinking is offered as a first step in these efforts and as a conceptual framework for educational practice. Future research is required to test this theory of systems thinking.

BIOGRAPHICAL SKETCH

Derek Cabrera is a doctoral candidate at Cornell University, a National Science Foundation (NSF) IGERT Fellow in Nonlinear Systems, and recipient of the Association of American Colleges and Universities' 2006 K. Patricia Cross Future Leaders Award. For fourteen years prior to Cornell, he worked in four continents, twelve countries, and fifteen US states as an experiential educator with Outward Bound and as a mountain and river guide with various outdoor organizations, and he also worked in service learning and restorative justice with the conservation corps movement in the US. He has led high-altitude climbing expeditions to some of the world's most remote mountain regions. He was an adjunct faculty member at Regis University, where he taught courses based on his original learning models. He is the author of the book *Remedial Genius: Patterns of Knowledge*. He has held director positions at Outward Bound, Palo Alto Red Cross, and the Montana Conservation Corps, where he led reorganization initiatives. He has worked in the for-profit, non-profit, government, and academic sectors. He was appointed by the Governor of Montana to the Legislative Interim Committee on Juvenile Justice and Mental Health. As a social entrepreneur, he founded CorpsLINK, the Restorative Justice Training Network, the Regis Leadership Corps, and several smaller programs. He holds Bachelor's and Master's degrees from Regis University.

ACKNOWLEDGMENTS

There are many people, programs, places, and a dog to thank. I first want to thank my family, especially my mother and father. Of course, there was the inception, which was very good for my future. But I also want to thank my parents because they taught me to think, to care, to be passionate about life, and to find that one thing that makes you feel alive when you are doing it. That thing, for me, is thinking about thinking. In particular, both my father and mother were gifted teachers who taught me many things about being a teacher without ever explicitly teaching me those things. I want to thank Peter Mason for teaching me to be incremental—that good works do not happen overnight but in tiny steps, and Scott Campbell, for teaching me the subtleties of politics and when not to say what is on my mind. Of course, I also want to thank my wife, Susan, for being so many things at so many times that naming them would fill more pages than the dissertation itself.

I have found Cornell University to be most things that a person could possibly imagine in an institution of higher learning: interdisciplinary, engaged, friendly, and rigorous, and a place that balances theory and practice in its organizational DNA. As part of this institution, I'd like to thank the many professors and staff people who welcomed me, a stranger with strange ideas, into their offices and who told me about their work and their lives or critiqued my own work. I'd also like to thank The National Science Foundation (NSF), The Santa Fe Institute (SFI), Cornell's Integrative Graduate Education and Research Training (IGERT) program in nonlinear systems; in particular, John Guckenheimer, Steven Strogatz, and Will Provine for teaching me about complexity, networks, and nonlinear systems, and my IGERT colleagues, from whom I have learned that interdisciplinarity is tougher going than its lofty idealism suggests and is really about hard work between people with different perspectives on a problem.

From what I've heard, the doctoral process can be a series of gates one passes through once he or she has been hazed sufficiently. This has not been my experience, and so, I want to thank the three very special members of my committee for making the process mostly enjoyable (as it should be) and always focused on learning. Special thanks go to Rosemary Caffarella for introducing me to a magical place called Cornell University and for guiding me through the intricacies of a literature review. I also wish to thank Will Provine, who taught me about evolution, Darwin, non-free will, and life. Will has sometimes been called the "world's greatest evangelical atheist"; he is also a man who disproves that spirituality and morality are linked, as he lives solely to find meaning in his relationships with those around him, is kind to a fault, and is a brilliant scholar. He has taught me far too many things to account for or to count. Finally, I want to thank William Trochim, who has been equal parts advisor, mentor, colleague, coach, therapist, and friend. He was also the Chair of my committee, and I could not have imagined finding a better one.

Thanks also to Dioji, our little blue cattle dog, for reminding me to play, which I am hoping to do a little of now that I am done.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Chapter One

Introduction

"Without changing our patterns of thought we will not be able to solve the problems we created with our current pattern of thought." –Einstein

This chapter offers an introduction to why people in many fields are drawn to and motivated to implement systems thinking. The reasons for its growing popularity are likely as diverse as those who believe it holds great promise. Yet beneath these reasons may lie a more fundamental explanation for the allure of systems thinking: it offers a model for thinking differently. Despite this allure, there is disagreement about what constitutes systems thinking, and its meaning is ambiguous. The purpose of this dissertation is to address and eliminate some of this ambiguity so that with each passing chapter, the reader gains more insight into what systems thinking is. Of course, most readers would prefer a description of systems thinking here, in the beginning, so that they can more adequately grasp what is being discussed. Alas, here lies the problem this dissertation hopes to remedy; that is, while a clear and concise description of systems thinking should appear early on, it is as yet impossible to offer one of any merit. The reader will have to wait until the end, with much discussion in between now and then, before a clear description of systems thinking can be provided.

In September 2005 a small team of doctoral students at Cornell University convened a weekly meeting with the intention of developing curriculum for a senior capstone course for Cornell students. The idea for the course was simple: it would be for departing seniors, taken during their last semester, and it would be the motivational equivalent of a commencement address that lasted 16 weeks. The team hoped that the course content, delivered by a host of inspirational faculty speakers, would frame "the crisis the planet faces" and motivate students to venture into the world with both a vision and a cause. The team of doctoral students included approximately 8 biologists (environmentalists, evolutionists, etc.) and an educator and interdisciplinarian. With a significant majority of the group being environmentally inclined, its initial conversations centered around the implicit assumption that the crisis was an environmental one, and that if only people could understand the scientific facts of the matter, it—the environmental crisis—could be more readily solved. Having worked at Outward Bound and with the Conservation Corps movement in the US, I was not averse to acknowledging the environmental crises our planet faces. But as I sat in that first meeting listening to these highly educated people speak passionately about the crisis, I also felt a growing sense of unease with the conversation. I restrained myself from blurting out that environmental issues were not the crisis! I resisted the temptation to derail the group's progress and opted for a more subtle approach. This team needed to engage in an experience that would broaden their perspective. What if we asked a group of faculty from across the disciplines to describe what they thought the crisis was and how they would solve it? Previous work in similar areas led me to believe that each faculty member would respond passionately from the perspective of his or her particular problem or project. If the team members engaged in this simple exercise, then presumably they would realize that highly trained scientists from other fields would answer the question differently. Perhaps environmental issues would be revealed as a relatively small set of concerns situated within a host of other scientific, social, political, economic, and cultural crises. Such an experiential exercise would be an ideal way to encourage these passionate biologists and environmental activists to broaden their view and to see the crisis from multiple perspectives. I suggested this idea and it was, somewhat to my surprise, met with enthusiasm. The group began to collect names of faculty members and devised an email explaining the question. The core of the email read:

> We would appreciate your response to the following questions: From your point of view, what is the nature of the global crisis we are facing? What steps might we take to solve it? If you had the opportunity to address the entire Cornell senior class for 15 minutes about this crisis, what would you say?

It is often the case with faculty members absorbed in their research and lecturing that emails are lost in the hustle and bustle of their busy lives. Response rates for faculty members are notoriously low. Yet, those who responded did so with enthusiasm—and their responses were, as predicted, fascinating and specialized. One researcher wrote:

> The world is treating sleep as a luxury, rather than a necessity. This is causing loss of quality of life, decreased productivity, obesity, accidents, illness and shortened lifespan. If I had my 15 minutes, I would talk about "sleep and peak performance for the rest of your life."

Another wrote:

> I have become quite passionate about the idea that if we eat the right food, there are few things that would have more impact on the future of our planet.

Another faculty member wrote a poem, and still others wrote about more traditional crises such as overpopulation, the United States' current disregard for international law, the environment, and moral degradation.

Each of us who studies an issue in depth and then is asked to consider the crisis is able to connect the passion we have for our topic to each of the larger global issues we face. The sleep researcher believes that sleep is the crisis. The environmentalist believes that global warming is the crisis. The soil scientist points to the degradation of soils as the result of intensive and unsustainable agriculture.

Through this process of listening to faculty respond to questions, many of us in the group began to question our initial assumptions about *the* crisis: if there are so many crises facing humankind, is there one root crisis? People who are drawn to a popular book on systems thinking, or practitioners in public health, education, or business who attempt to implement systems thinking in their organizations, or scholars and researchers who study systems thinking, may unknowingly be asking the same question. Surely, each of these people faces different problems or is concerned about different crises, but each is drawn to systems thinking. Why? One answer may be that the root crisis—the crisis common to all crises—is in the way we think. The popularity of conceptual frameworks such as systems thinking may be an implicit cry for a solution to the root crisis—the crisis of conceptualization.

That the root crisis lies in the way we think is not a new idea. Several prominent scholars have expressed that the crisis is really *a crisis of perception*.[1-7] In my view, however, while perception does involve cognitive processes, it is also more intimately linked to sensation via the sensory organs, and there is less we can do, save develop more advanced implant technology, to increase our senses of perception—to see or hear better or to enhance our senses of smell or taste. The world of conceptualization, on the other hand, is infinitely adaptable. Changing the way we *think*—the way we conceptualize—is a much more feasible task than changing the way we *sense*. Therefore, I make a distinction between the crisis of perception and the crisis of conceptualization, although the two are related.

That the root crisis is conceptual is an important realization, because as we venture into the tangled overgrowth of the systems thinking literature, at times it will be helpful to remember why people are clamoring to learn more about systems thinking. Systems thinking has become increasingly popular because people believe it may provide one solution to the root crisis…the crisis of how we think…the crisis of conceptualization. Although people may view systems thinking as a kind of solution, however, because the construct of systems thinking is so unclear, it is possible that people see its potential even while they do not yet entirely understand what it is.

The realization that the crisis is conceptual is also important because it reveals my own biases on the topic. I approach systems thinking as an educational theorist first. There are many possible entry points or perspectives to systems thinking. For example, a historian might trace the evolutionary epistemology of the systems concept to present-day systems thinking. Someone else might approach it how? As an educational theorist, I am concerned with the conceptual development of people, and I am convinced of the central role education plays in social change. Education is a dynamic lever for these two outcomes—individual conceptual development and aggregate social change—and it is the sole reason I chose to be an educator rather than a scientist or a day trader.

Even the consummate naturalist Charles Darwin realized that education was the lever for individual development and social change. In one of the famous journals he entitled "Old & Useless Notes," Darwin wrote what has been for me a call to action: "Believer in these views will pay great attention to Education."[8(p608)] Although short, this statement packs considerable weight. When he uses the term "these views," Darwin refers to his expansive ideas on evolution and its implication for the lack of human free will. It is clear that Darwin's theory of evolution is one of the most, if not the most, influential idea ever conceived by a human mind. The famous evolutionary biologist Theodosius Dobzhansky wrote that "nothing in biology makes sense except in the light of evolution."[9] In the next century—what some are calling the "Century of Biology"—the full impact of Darwin's ideas will inspire even greater awe. So, too, will his beliefs on the lack of human free will as a direct implication of evolution gain wider acceptance. If Darwin is right—and he has been right about a lot—we will perhaps begin to "pay great attention to Education." I agree with Darwin that education is the most effective lever of social change. And I do not mean to limit the definition of "education" to its traditional forms but rather extend it to all forms, from

K-12 to adult, from formal to informal, from traditional to alternative, and from organism to organization.

Therefore, it is as an educational theorist that I approach systems thinking. In particular, I have examined the challenges of implementing systems thinking in public health. Public health leaders and practitioners (as well as those in business, education, and science) are keenly interested in systems thinking. This interest needs to be met with educational clarity at every level and in every form—from K-12 to adult, from formal to informal, from traditional to alternative, and from organism to organization.

My thoughts on the matter, and my biases, revert to the root crisis of conceptualization. When I get lost in the forest that is systems thinking, I find my bearings by asking myself a pragmatic question: why do people want to implement systems thinking in the first place? The answer is that they perceive the need to change how they, or others, think.

Changing the way we think does not automatically solve the various crises facing the planet. However, it does reframe how we think about those crises, what we view as a problem in the first place, and what solutions might look like. Even after our thinking is changed, much hard work remains to solve these problems. Systems thinking alone will not heal the human condition. Whether the problems are local (e.g., organizational management, life management, parenting) or global (e.g., global warming, food security, violence, terrorism, public health, and even sleep deprivation), it is the vigorous problem-solving efforts in each of these areas, informed by a systems thinking perspective, that that will act as a salve for the human condition.

There are many ways to think about systems thinking. Some scholars view it as a specific methodology, such as system dynamics, while others believe it is a plurality of "methods." Others see systems thinking as systems science, while others see it as a general systems theory. Still others see systems thinking as a social movement. These differentiations, and others, will be made clearer in the chapters that follow. I view systems thinking as conceptual. That is, while systems thinking is informed by systems ideas, systems methods, systems theories, the systems sciences, and the systems movement, it is, in the end, differentiated from each of these things.

It is necessary to reiterate this point about systems thinking being conceptual because it is perhaps the central distinction and contribution to the field of systems thinking that I hope to make herein. I propose that the question “what is systems thinking?” cannot be answered by a litany of examples of systems thoughts (or methods, approaches, theories, ideas, etc.). Such a response is analogous to answering the biologist’s question “what is life?” with a long list of kingdoms, phyla, classes, orders, families, genus, and species. Taxonomy of the living does not provide an adequate theory for life. Likewise, taxonomy of systems ideas, even a pluralistic one, does not provide an adequate theory for systems thinking. I propose that this distinction—that systems thinking is, like life, a *patterned* phenomenon—is essential to understanding systems thinking, especially in light of the considerable confusion about it in the literature. Those scholars who have made gracious attempts at pluralism in the vast field of systems thinking have tended to define systems thinking by making taxonomic lists of examples of systems thinking. I submit that there are many examples of systems thoughts but that these are not the same as a construct of systems thinking. A pluralistic framework or theory of systems thinking will be, in the end, a conceptual pattern. It bodes well then, if the root crisis is also a conceptual one, because it means that systems thinking may be one of the solutions to the problems we all face.

The reasons for the popularity and promise of systems thinking are extensive; however, all of these reasons point to the need to change the way we fundamentally think. The need to change the way we think is an appropriate introduction to the remainder of this dissertation because an exploration of systems thinking is, at its core, a journey into how we think. In Chapter 2 the literature of systems thinking will be reviewed in order to explicate the history of systems thinking and the field's contributors and ideas. Chapter 3 dives deeper into four pervasive, influential, and philosophically important ambiguities in the literature. In particular, these ambiguities are central to how the systems thinking construct is defined. Chapter 3 concludes with new perspectives on each of these ambiguities. Chapter 4 transitions from the general to the specific by exploring how systems thinking is being applied in one case—the case of public health. Implicit throughout the discussion in this chapter is the idea that the problems faced by public health practitioners are generalizeable to those faced in by professionals in many other fields where systems thinking is being implemented. Chapter 4 sets the stage for an empirical research study that attempts to clarify what these challenges are and to what extent they are influenced by the broader ambiguities found in the systems thinking literature. Chapter 5 details the research methodology used and four of the steps in the research process. Chapter 6 offers the results of this case study and suggests various interpretations of these results. In Chapter 7 we revisit the construct of systems thinking in an attempt to differentiate it from similar terms. In addition, this chapter suggests that educational practitioners and researchers play a vital role in the development of systems thinking. Also in Chapter 7, a theory of systems thinking called DSRP is proposed. It is suggested that future research, as well as parallel implementational, empirical, and educational efforts, are needed to test this theory.

Chapter Two

Review of Systems Thinking Literature

This chapter introduces the literature in the field of systems thinking. The criteria used for the literature selected is explained. Because there is great confusion about the difference between similar concepts such as systems thinking, systems sciences, systems theory, and systems methods, the review of the literature pays particular attention to differentiating and relating these terms. In addition, the broad literature on systems is differentiated into categories such as "knowledge about systems" and systems thinking and, subsequently, into popular and scholarly strands of literature. This chapter will provide the reader with the necessary context for a deeper discussion of the construct ambiguities of systems thinking in the next chapter.

Boote and Beile[10] write, "a substantive, thorough, sophisticated literature review is a precondition of doing substantive, thorough, sophisticated research."[10(p1)] In particular, Boote and Beile explain that educational researchers must take extra precaution where the literature review is concerned because of the often "messy" and complicated nature of educational problems. They propose that the literature review is a way of "learning from prior research on the topic"[10(p.3)] and of building "on the scholarship and research of those who have come before us,"[10(p3)] and they differentiate between the research involved in a particular study and its scholarship (the latter being central to a good literature review). In their own research on the "centrality of the literature review," Boote and Beile built on Hart's[11] criteria and developed a 12-item scoring rubric[10(p7)] for rating literature reviews. This rubric includes low, medium, and high scales for 5 categories: (1) coverage, (2) synthesis, (3) methodology, (4) significance, and (5) rhetoric.[10] Boote and Beile's five criteria were chosen for this literature review because they promote, at least implicitly, an important notion: that the literature review, or any cognitive, conceptual act for that matter, should be methodological. That is, it should be guided by some transparent method which, once applied, would lead any reasonable person to similar conclusions.

Coverage of the Literature

The first criteria of a literature review must necessarily be what to include and exclude from the review. The decisions to include or exclude certain publications or viewpoints or categories of publications of viewpoints must be justified[10(p8)] in a transparent way. Systems thinking is more like an idea that crosses many fields and disciplines and is interpreted in many different ways. One of the fathers of one type of systems thinking (general systems theory), Ludwig von Bertalanffy writes, "an attempt to summarize the impact of 'systems' would not be feasible."[12(p5)] Similarly, the allied fields of public health are vast. In Trochim, et al.,[13] the public health system is characterized as complex: "Modern public health practice encompasses a complex, loosely coupled system of actors including governmental entities at the international, national, regional, and local levels; a diverse conglomeration of nongovernmental organizations (such as foundations, advocacy and special interest groups, coalitions and partnerships, for-profit and nonprofit medical systems, and businesses); and citizens in the public at large." In addition, the public health arena deals with a "broad array of threats to well-being, ranging from obesity and tobacco use to violence and infectious diseases."[13(p2)] In each of the areas mentioned there exists one or more areas of scholarship. Therefore, both of these areas of scholarship—systems thinking and public health—are inappropriately large for a literature review of this scope. In fact, these fields are so large that it is questionable whether such a comprehensive literature review is feasible.

The intersection of these two vast arenas of scholarship is a more manageable task both because it is a relatively new set of connections that scholars are making and because there are more narrow boundaries as to what constitutes a publication on the topic. Therefore, publications were chosen for inclusion based on a number of criteria. First, any publications in reputable public health journals such as the *American Journal of Public Health*, the *Journal of the Association of American Medicine*, *Lancet, Nursing Research, Health Care Management Review, Social Science and Medicine*, and *Current Opinion in Infectious Disease*, among others, were chosen if they contained the search term "systems thinking" in any of the data fields. This criterion is justifiable because "systems thinking" is a phrase that is rarely used without explicit reference to the idea of systems thinking. For example, systems thinking would almost rarely be a random word string in a common sentence as it is not grammatical; even Microsoft Word's grammar checker identifies the term as questionable. Therefore, it is likely that any publication that contains the term "systems thinking" is referring to the same types of thinking that are the focus of this review. If one were to search for the terms separately, as in "systems" or "thinking," the resulting list of publications would be far too large for a viable literature review; the individual terms "systems" and "thinking" are very general and will occur in numerous publications that have little or nothing to do with the notion of systems thinking.

The second criteria used for inclusion is the network of citations that are created from any set of related publications. In the case of the list of publications generated by the first criteria, numerous other publications were identified based on (1) the citing author's comments on the publication and (2) the bibliographical information. This linking of one publication to another through references and ideas is central to scholarly and scientific practice and, while qualitative in its execution, is a reasonable method for identifying relevant publications in a sea of information. One method for checking the completeness of this type of search and inclusion is to pay attention to what can be called "closure in the citation network," which simply means that one begins to see loops in the linkages between publications; once the majority of relevant citations point to publications that have already been included, one can reasonably claim that the literature is "coming full circle."

The final criterion used for inclusion of publications in this review is a time-tested social technique for reducing large quantities of information into reliable conclusions: word of mouth based on credibility. Having worked with many people on several publications (e.g., public health professionals and scholars, systems thinking experts, and experts in ontological systems,[1] and as a member of numerous email discussion groups and other social-scholarly forums), the author has developed a reasonable filter for what is relevant to "systems thinking and public health." The author has also developed a social network of trusted colleagues who guide one another to relevant publications on the topic. Like the second criterion, this third criterion may seem exceedingly biased; is it not possible that two reasonable people belonging to the same email discussion groups and social circles could reasonably arrive at a different set of included publications? Yes, this is possible, but not probable. Word of mouth based on individual reputation may be humankind's longest-standing and most reliable method for cutting through noise to find reliable signal. For example, amazon.com's customer recommendations and viral marketing techniques (marketing that uses word of mouth rather than traditional media such as television and radio) both rely on the collective knowledge of groups that share similar interests and the word-of-mouth criteria used by these groups. Self-organized, aggregate recommendations are not "un-biased," but they are one heuristic for reliably identifying what to include.

---

[1] The term "ontological system" is used throughout to refer generally to systems that exist in contrast to how we think about systems. Merriam-Webster's online dictionary defines *ontological* as "relating to or based upon being or existence" (http://www.m-w.com). So knowledge about an ontological system, for example, would include knowledge about specific systems such as an organism, an epidemic, or any specific physical, natural, or social system.

Synthesis of the Literature

Boote and Beile[10] explain that synthesis in literature reviews enables one to "clarify and resolve inconsistencies and tensions in the literature,"[10(p7)] thereby making a contribution to the field by "developing theories with more explanatory and predictive power, clarifying the scope and limitations of ideas, posing fruitful empirical investigations, and/or identifying and pursuing unresolved problems."[10(p7)] They propose 6 sub-criteria for developing a synthetic view in literature reviews. Subsequently, they propose that the highest-scale (the 3rd of 3) criteria for developing a synthetic view involves a critical view. As a transparent method for synthesis, this study will use Boote and Biele's criteria. Table 2.1 explains their criteria in relation to this highest scale[10(p8)]:

Table 2.1: Boote and Biele's "Literature Review Scoring Rubric" (adapted for tense only from [10(p8)])

Criterion	Scale (3 on 1–3 scale)
Distinguish what has been done in the field from what needs to be done	Critically examine the state of the field
Place the topic or problem in the broader scholarly literature	Clearly situate the topic in broader scholarly literature
Place the research in the historical context of the field	Critically examine the history of the topic
Acquire and enhance the subject vocabulary	Discuss and resolve ambiguities in definitions
Articulate important variables and phenomena relevant to the topic	Note ambiguities in the literature and propose new relationships
Synthesize and gain a new perspective on the literature	Offer a new perspective

With this literature review criteria as a guide, the broader scholarly literature of systems thinking will be reviewed.

The Broader Scholarly Literature of Systems Thinking

This section reviews the broader systems literatures as context for systems thinking as applied in a public health setting. For heuristic purposes, the literature is described in terms of its structure (e.g., the content and categorical organization of different types of publications) and its dynamics (e.g., how the different structures interact).

Structure of the Systems Literature. The concept of systems is so broadly applicable and has been in use for so long that it is ubiquitous in scientific literature, making analysis of this vast and complicated terrain difficult. The systems literature can be divided into two heuristic components: knowledge-about-systems, which is *ontological,* and systems thinking, which is *conceptual* and/or *epistemological*.

There exists an important difference between ontological knowledge-about-systems and the general conceptual "habits of mind" that can be derived from such knowledge (e.g., systems thinking). Knowledge-about-systems is a loose "ecology" of descriptions and predictions of systemic ontological phenomena, whereas systems thinking is a conceptual orientation informed by this knowledge. The focus herein is on systems thinking, although some discussion of knowledge-about-systems is necessary, especially some of the more general and important systems phenomena. The term systems thinking is often found in popular books that target a general audience and in academic journals that target a specialist audience. Yet the term is less commonly used, or not used at all, by scientists in the physical, biological, or social sciences despite the fact that these scientists think deeply about systems and seek to find general principles and patterns of systems. Thus, the boundary between knowledge-about-systems and systems thinking is not clearly defined but does serve as a useful heuristic.

Systems thinking literature can be further divided into two types: scholarly systems thinking in academic journals, and popular systems thinking in the public presses. Figure 2.1 illustrates the structure of these systems literatures using the metaphor of two landmasses separated by a water-filled canyon. Note that for illustrative purposes, the number of human figures denotes the relative sizes of these literatures in terms of numbers of publications.

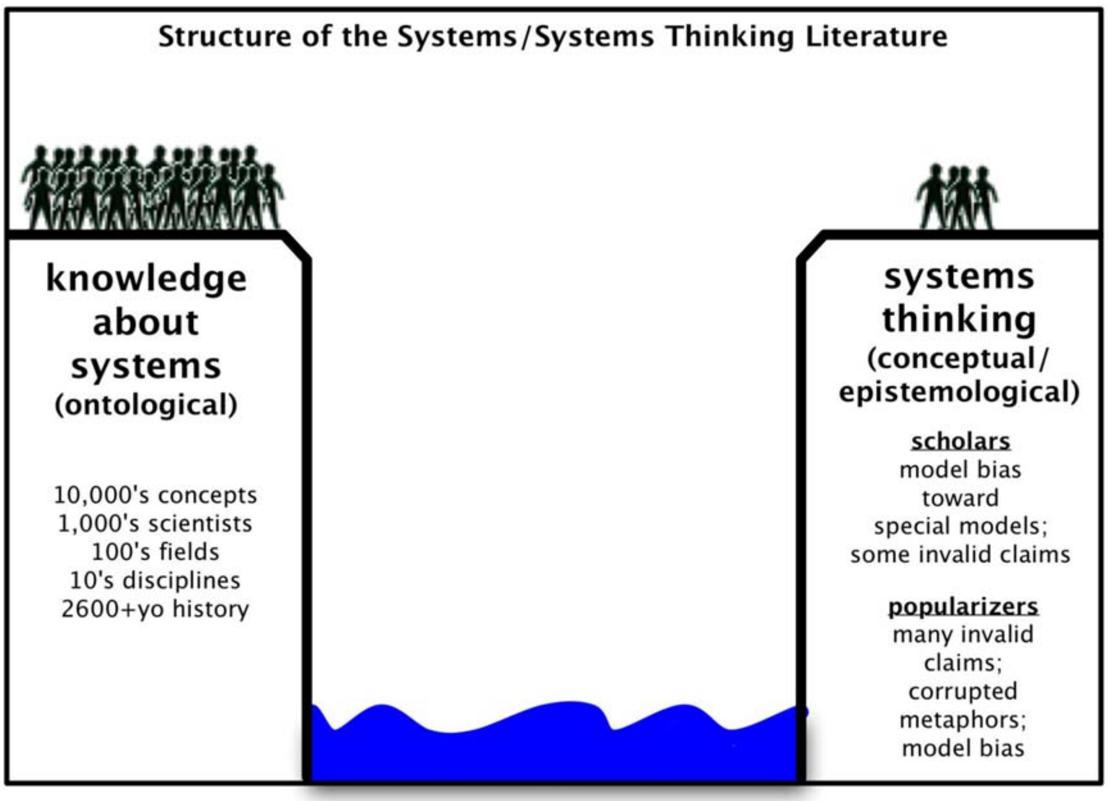


Figure 2.1: The Structure of the Systems Literature

Knowledge About Systems. The development of knowledge-about-systems began nearly 2,600 years ago with Lao Tsu, who in the *Tao Te Ching* wrote what is perhaps the first formal description (albeit in verse) of a system when he described the forces of yin and yang.[14] Today, in scientific terms, these naturalistic forces would be described as coupled oscillators. In the bestselling book *The Tao of Physics*,[15] Capra details the similarities between modern physical science and Taoist philosophy. Bertalanffy[12] also elucidates the long history of the systems concept when he writes:

> As with every new idea in science and elsewhere, the systems concept has a long history. Although the term "system" itself was not emphasized, the history of this concept includes many illustrious names. As "natural philosophy," we may trace it back to Leibniz; to Nicholas of Cusa with his coincidence of opposites; to the mystic medicine of Paracelsus; to Vico's and ibn-Kaldun's vision of history as a sequence of cultural entities or "systems"; to the dialectic of Marx and Hegel, to mention but a few names from a rich panoply of thinkers. The literary gourmet may remember Nicholas of Cusa's *De ludo globi* and Hermann Hesse's *Glasperlenspiel*, both of them seeing the working of the world reflected in a cleverly designed, abstract game.[12(p408)]

There are likely too many discrete chunks of knowledge about systems to count, a very broad range of scholars who could in some way be described as systems thinkers, and many disciplines and fields that both influence and are influenced by a systems orientation. Some of these systems ideas are philosophical, while others are scientific, involving empirical research on highly specialized systems. Still others are applied systems concepts in areas such as business, education, and public health. In the vast network of ideas and people bonded by the "big idea" of systems, how can anyone hope to sort it all out? Consider the following partial list that includes systems concepts from the contemporary physical, natural, and social sciences[13]:

> Particularly [to] one who is approaching the issue of systems thinking and modeling for the first time, the depth and breadth of systems science can be bewildering. Just consider a few of the topics that are associated with the general area of systems thinking: causal feedback, stocks and flows, open and closed systems; centralized, decentralized, heterarchical, hierarchical, and self-organizing systems; autopoiesis; nonlinear systems and chaos; complex adaptive systems; boundary conditions, scaling, power laws, phase transitions, universality and renormalization; silo effects; emergence; cellular automata; fractal self similarity, general systems theory, cybernetics, control theory, information theory, computational simulation, decision and game theory, system dynamics; evolution, biology and ecology; small world phenomena; and set, graph and network theory.[13(p2)]

Bertalanffy states, “An attempt to summarize the impact of ‘systems’ would not be feasible.”[12(p5)] Therefore, Bertalanffy explains, “A few examples, more or less arbitrarily chosen, must suffice to outline the nature of the problem and consequent re-orientation.”[12(p5)]

Despite its proposed infeasibility, three scholars—Midgley, Francois and Schwarz—have made separate attempts to encapsulate the long history and vast terrain of knowledge-about-systems. Midgley acted as editor to the most complete review of systems thinking available today. Midgley’s four-volume collection, entitled *Systems Thinking*,[16-19] includes ninety-seven papers that he and an International Advisory Board of “forty-seven distinguished writers from across the spectrum of the systems movement”[16(p5)] thought were seminal.

While Midgley called this collection, *Systems Thinking*, in spite of this title, the work is actually a collection of scientific and conceptual papers from the knowledge-about-systems literature rather than systems thinking per se. It is an important source for a history of the systems movement. It is unclear whether Midgley would agree with this assessment, but his choice of words in his introduction to the volumes uses similar but different terminology interchangeably. For example, he alternatively explains the purpose of the volume (emphases added): “[it] aims to consolidate key writings on *systems thinking*”; “I have attempted to represent the broadest possible range of *systems ideas*”; “the huge variety of *systems ideas* is the major strength of the *systems movement*”; “I am more familiar with some *strands* of *systems thinking* than others”; “drawing upon the full variety of *systems ideas*.” These explanations belie Midgley’s casual use of the terms “systems thinking,” “strands of systems thinking,” “systems ideas,” and “systems movement.”

These terms are not interchangeable: an idea about how a system works is not the same as a pattern of thinking that is systems oriented. The systems movement is a historical account of the people, ideas, and publications that cohere around a particular topic, but it is not a conceptual framework. Furthermore, the differentiation between these similar terms is central to the work herein; as educators attempt to teach the meta-conceptual skills of systems thinking they need a clear definition or theoretical model of systems thinking.

Systems thinking is not a science, it is a conceptual framework. There is no science called systems thinking, although there are sciences called complexity, cybernetics, and nonlinear dynamics. Despite this confusion, Midgley claims to provide a history of systems thinking (which in the framework presented here would be called systems concepts or knowledge-about-systems) that he describes as having occurred in "three waves": physical, social, and critical. Alternatively, he organizes this litany of ideas into four related groups: (1) general systems theory, cybernetics, and complexity, (2) systems theories and modeling, (3) second-order cybernetics, systems therapy, and soft systems thinking, and (4) critical systems thinking and systemic perspectives on ethics, power, and pluralism. While Midgley's edited volumes are, to be sure, one of the great contributions to the systems movement, it is clear, as noted earlier, that neither his introduction nor the ninety-seven papers he chose to include represent systems thinking as a conceptual framework. While Midgley provides ninety-seven examples of systems concepts, he does not provide an integrated framework (a model) for systems thinking. This is akin to providing ninety-seven descriptions of living organisms and then proposing that one has answered the question "what is life?" What Midgley does provide, which is of utmost importance, is a litany of systems ideas and a history of the systems movement.

In another attempt to summarize systems concepts, Francois assembled the two-volume *International Encyclopedia of Systems and Cybernetics,*[20] which contains 3,800 distinct systems concepts. Some of these concepts—such as cybernetics—are entire fields in and of themselves composed of many more systems concepts. While Francois offers a wide-angle view of the systems landscape, it is a snapshot with very low resolution. One senses that knowledge-about systems is a vast intellectual domain, but Francois' accounting lacks the detail needed to penetrate into the systems concept. On the other hand, Francois bridges the knowledge-about-systems and systems thinking literatures by providing a encyclopedic collection of systems concepts. This collection of concepts in turn can be used to look for patterns of thinking that are fundamental to these concepts.

Likewise, Schwarz[21] developed a map (Figure 2.2) entitled "Some Streams of Systemic Thought" that is similar to Francois' *Encyclopedia*, but in visual form serves as an illustration of the bewildering breadth of knowledge-about-systems. Perhaps the most significant contribution of Schwarz's map is its ability to make a daunting impression upon the reader of the vastness of this literature. The over 1,000 nodes that make up the network map include both broad topics, such as "evolution," and specific ones, such as "bifurcated cultures," as well as references to scholars as diverse as the Eastern mystic Lao Tsu and the new-millennium biologist Lynn Margulis. Schwarz's map uses color to indicate different disciplines, and the nodes are placed historically from the bottom (ancient) to the top (recent). It is significant that Schwarz' map makes the link between knowledge-about-systems and systems thinking, in title alone, when he describes the large network of concepts and scholars aptly as "some streams of systemic thought." Here again, similar to the works of Midgley and Francois, Schwarz's map helps systems thinking scholars to organize the many systems concepts as a basis for future efforts to identify patterns of thinking that are fundamental to these concepts.

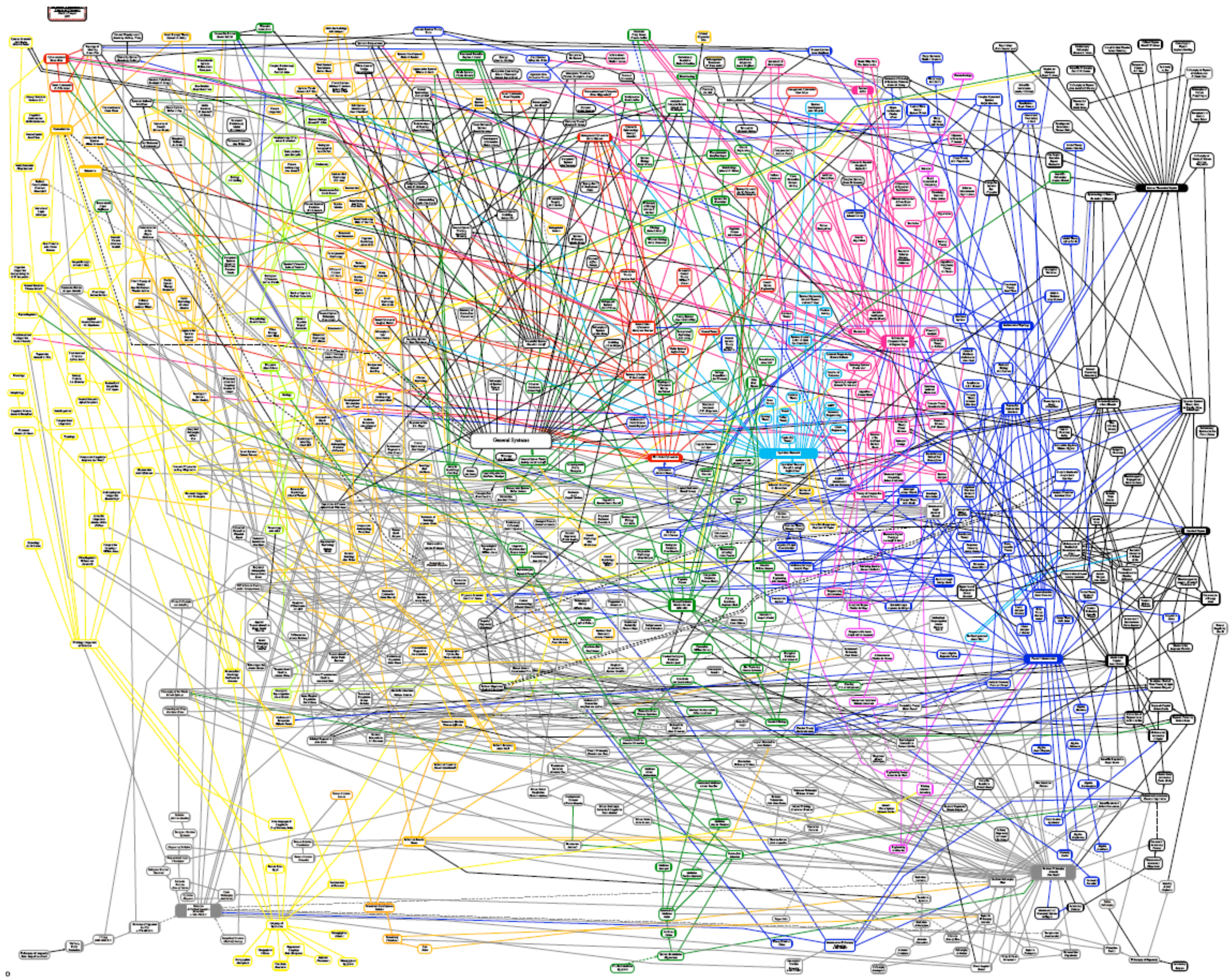


Figure 2.2: Schwarz's "Some Streams of Systemic Thought"[21]

Schwarz and Francois offer a wide-angle but low-resolution view of knowledge-about-systems, while Midgley bridges (Figure 2.3) the systems thinking and knowledge-about systems literatures with greater detail than Francois and Schwarz. Francois, Schwarz, and Midgley provide a bridge between knowledge-about-systems and the systems thinking literatures and in doing so offer an aggregate, but not integral, perspective.

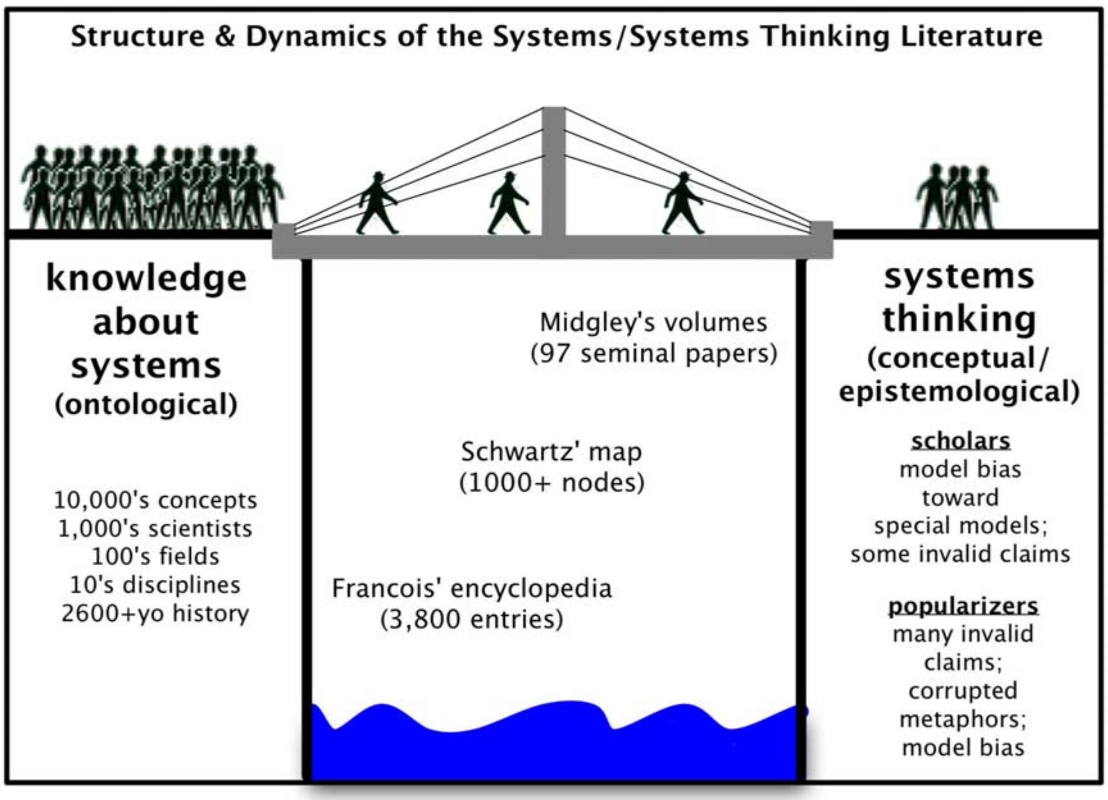


Figure 2.3: Bridge Builders Between Knowledge-About-Systems and Systems Thinking

High-resolution detail of the systems concept and its application to various disciplines, phenomena, and problems can only be found in a careful reading of the many publications that focus on the varied aspects of various systems. To give the reader an idea of the diverse scientific literature having to do with ontological systems, but not directly with systems thinking, Table 2.2 provides a representative list of paper titles published in scientific journals and publications.

Table 2.2: Publications about Ontological Systems

Title	Discipline(s)
Modeling the Firm as a Network[22]	Management & Organizations, Network Theory
Scaling Patterns in Exotic and Native Bird Species Distribution and Abundance[23]	Ornithology
The Structure and Function of Complex Networks[24]	Mathematics, Network Theory
Formal Aspects of the Emergence of Institutions[25]	Business
Scale-Free Networks [26]	Biology, Mathematics
Modeling the Evolution of Human Trail Systems[27]	Biology, Psychology, Sociology
Predicting Where We Walk[28]	Biology, Psychology, Sociology
The Power of a Good Idea: Quantitative Modeling of the Spread of Ideas from Epidemiological Models [29]	Epistemology, Epidemiology
Special Scale-Invariant Occupancy of Phase Space Makes Entropy S_q Additive[30]	Physics
How Individuals Learn to Take Turns: Emergence of Alternating Cooperation in a Congestion Game and the Prisoner's Dilemma[27]	Sociology, Economics
Elite Transformation and Organizational Invention in Renaissance Florence[31]	Anthropology, Epistemology

The systems orientation influences scientists in many disciplines who in turn generate knowledge-about-systems in many forms. The paper titles in Table 2.2 do little more than scratch the surface of the many writings that address systems concepts and which may, in turn, influence the concept of systems thinking. Because the term systems thinking is vague, it is unclear whether these authors are "systems thinkers" or are merely "thinking about systems." What may be reasonably concluded is that these authors are using a patterned form of thinking that is differentiable from non-systemic forms of thinking. These underlying patterns in their thought are foundational to understanding what systems thinking is and how it differs from thinking in general or from thinking about systems. A more complete discussion of this issue will occur in Chapter Seven.

A complete review of the literature on knowledge-about-systems is not only difficult to imagine; it is also not the purpose of this study. For our purposes, three significant themes emerge from this literature. First, the knowledge-about-systems literature is varied and diverse, spanning the disciplines of the philosophical, mathematical, physical, chemical, biological, economical, psychological, social, and applied sciences, and describing or predicting ontological phenomena using systems theories, concepts, and methods.

Second, while the authors of this literature share a common "systems orientation," more often than not they are unaware of each other. Scholars may think of themselves as philosophers, physicists, biologists, ecologists, psychologists, sociologists, engineers, or economists but not as systems thinkers. No scientific journal or conference exists for this type of systems thinker in the broad sense of the term (e.g., scientists do not attend conferences as "systems thinkers"). The term exists only in the descriptive domain of those who study science, scientists, or thought models as phenomena in and of themselves.

Third, the collective findings of knowledge-about-systems are akin to a "resource mine" for systems thinkers. Knowledge-about-systems literature is a vast repository of scientific knowledge—a resource that is used to manufacture various conceptual orientations and applications. In particular, knowledge-about-systems is used as a resource to develop general conceptual frameworks with which to think about and, in turn, generate, new knowledge-about-systems. This feedback between the scientific, ontological knowledge-about-systems and the conceptual, epistemological systems thinking will become more important in the future. Although this mutual dependence is not at all explicit, as the systems thinking literature becomes more sophisticated, it will in turn become more relevant to the development of knowledge-about-systems.

Implicit in the key themes noted is the idea that knowledge-about-systems (an ontological activity), while related to and a resource for systems thinking is not itself systems thinking. What follows is a discussion of systems thinking.

Systems Thinking Literature

Systems thinking is not a science; it is a conceptual framework. Systems thinking is different from knowledge-about-systems. It is a conceptual orientation that is both informed by and may inform the scientific knowledge-about-systems.

Like many scholars, Bertalanffy confuses the issue by using the terms systems (a.k.a. knowledge-about-systems) and systems thinking inconsistently. At times he uses these terms to mean different things, while at other times he uses them interchangeably. For example, Bertalanffy writes, “If someone were to analyze current notions and fashionable catchwords, he would find ‘systems’ high on the list. The concept has pervaded all fields of science and penetrated into popular thinking, jargon, and mass media.”[32(p1)] Here, Bertalanffy is explaining the ubiquity of the systems concept across the sciences; he is talking about (ontological) knowledge-about-systems. In the next sentence, however, Bertalanffy shifts from using the term “systems” to using the term “systems thinking” but continues his thought as if these terms refer to the same thing. “Systems thinking plays a dominant role in a wide range of fields from industrial enterprise and armaments to esoteric topics of pure science. Innumerable publications, conferences, symposia and courses are devoted to it.”[12(p1)] In fact, relatively few publications, conferences, symposia and courses address the topic of systems thinking. Of course, many such events are devoted to various systems phenomena, that is, knowledge-about-systems.

Popular Systems Thinking Literature

When Bertalanffy tells us that the concept of systems has "pervaded all fields of science" he is referring to scientific studies of ontological systems; when he explains that the systems concept has "penetrated into popular thinking, jargon, and mass media," however, he is describing a different kind of systems concept. More specifically, he is describing an orientation toward systems thinking that has led to numerous popular books on the topic. The following is a sampling of some of these popular accounts of systems thinking.

Fritjof Capra, a self-described systems theorist, physicist, and best selling author, has written numerous books and popular articles on systems thinking,[2, 3, 32-59] ecological thinking,[33] and sustainability,[3, 33-35] including most recently, *The Hidden Connections: Integrating The Biological, Cognitive, and Social Dimensions of Life into a Science of Sustainability*,[33] and *The Turning Point: science, society and the Rising Culture*,[36] which was made into the popular film *Mindwalk*,[37] which depicts a documentary-style conversation about systems thinking between a famous poet, a world-class physicist, and a presidential candidate.

Margaret Wheatley wrote *Leadership and the New Science: Discovering Order in a Chaotic World*,[38, 39] in which she offers a new leadership paradigm based on the systems concepts of self-organization, chaos, and quantum theory.

Linda Booth Sweeney's *When a Butterfly Sneezes: Systems Thinking for Kids Big and Small*[40] provides children and parents an overview of systems thinking and reviews twelve popular children's books (e.g., Dr. Seuss's *Butter Battle Book*[41]) for systems concepts.

Building on the theories of networks, chaos, and complexity, Malcolm Gladwell's bestseller, *The Tipping Point: How Little Things Can Make a Big Difference,*[42] captured the public's imagination and led to new forms of viral marketing, among other things.

Noted organizational learning expert and management guru Peter Senge introduced to the world his version of systems thinking by selling over 400,000 copies of his national bestseller, *The Fifth Discipline: The Art and Practice of the Learning Organization*, as well as other publications on systems thinking.[5, 43-47]

A simple search of Amazon.com yields 21 books with "systems thinking" in the title, and there are many other popular books that do not use the term systems thinking but strongly promote a conceptual systems orientation of some kind. A few popular titles include: *Complexity: The Emerging Science at the Edge of Order and Chaos*[48] *Sync: the emerging science of spontaneous order*[49] *Six Degrees: The Science of a Connected Age;*[50, 51] and, *The Systems View of the World: A Holistic Vision for Our Time*.[52] These are just a few examples of popular systems thinking literature.

It is important to note that while some of the popular literature on systems specifically refers to the term "systems thinking," other works do not. Wheatley, for example, applies "new sciences" to business and public arenas. However, while Wheatley does not explicitly refer to systems thinking, the new sciences (e.g., chaos and complexity) are all systems-oriented sciences. Similarly, the popular writings of Capra, Richmond, Senge, and Lazlo explicitly refer to systems thinking but also use other contextualized synonyms for systems thinking such as "systems view" or "ecoliteracy." Table 2.3 includes a small sampling of some of the recent popular books on systems thinking or systems ideas.

Table 2.3: Sample of Popular Systems Thinking Literature

Author	Year	Title	Topic/Theme
Capra, F	1990	*The Turning Point: Science, Society, and the Rising Culture*	New ways of perceiving informed by systems view
	1996	*The Web of Life: A New Scientific Understanding of Living Systems*	New ways of perceiving informed by organismic view
	2002	*The Hidden Connections: Integrating the Hidden Connections among the Biological, Cognitive, and Social Dimensions of Life*	New ways of perceiving informed by ecological literacy
Capra, B	1992	*Mindwalk [movie]*	New ways of perceiving informed by systems view
Wheatey, M	1992	*Leadership and the New Science: Learning About Organization from an Orderly Universe*.	New ways of leading organizations informed by new systems sciences
Sweeney, LB		*When a Butterfly Sneezes: A Guide for Helping Kids Explore Interconnections in Our World through Favorite Stories*	Connecting various children's books to their underlying systems concepts
Senge, P	1990	*The Fifth Discipline: The Art and Practice of The Learning Organization*	Learning organizations and systems thinking
	1999	*Elegant Solutions: The Power of Systems Thinking*	Systems thinking
	2005	*Presence: Exploring Profound Change in People, Organizations, and Society*	Broad new ways of thinking

Table 2.3 (Continued)

Author	**Year**	**Title**	**Topic/Theme**
Laszlo, E	1996	*The Systems View of the World: A Holistic Vision for Our Time*	New ways of perceiving based on holistic view
Gladwell, M	2000	*The Tipping Point: How Little Things Can Make a Big Difference*.	Relevant, practical, historical examples linked to chaos, complexity and nonlinearity
Waldrop, M	1992	*Complexity: The Emerging Science at the Edge of Order and Chaos*.	The history of SFI and the emergence of complexity science
Strogatz, S	2003	*Sync: The Emerging Science of Spontaneous Order*	How things "sync" with each other and create order
Watts, DJ	1999	*Small Worlds: The Dynamics of Networks Between Order and Randomness*	Network theory explaining why it feels like a small world even though its big
Gell-Mann, M	1995	*The Quark and the Jaguar*	New ways of doing science from a complexity view

Scholarly Systems Thinking Literature.

Popular accounts of systems thinking overlap with the scholarly literature on systems thinking as well as, in some cases, on knowledge-about-systems. In a sense, these overlaps act as a "bridge" between the popular and scholarly systems thinking literatures as well as between the systems thinking literature and the knowledge-about-systems literature. For example, Senge, Sterman, Capra, and Laszlo publish in both academic journals and popular presses, while scientists such as Nobel laureate Murray Gell-Mann[53, 54-62] or applied mathematician Steve Strogatz[49, 63-65] both write popular books as well as scientific publications. Note that scientists such as Gell-Mann or Strogatz do not use the term "systems thinking," but their popular books on topics such as sync in systems, nonlinear systems and chaos, or complex systems sciences are related to systems thinking. The examples above demonstrate different types of literature that act as bridges between the popular and scholarly systems thinking varieties.

Systems thinking literature in scholarly journals is small but developing. Scholarly systems thinking cuts across the physical, natural, and social sciences,[12, 32, 33, 35, 37, 66-75] as well as in fields as diverse as the military-industrial complex,[76] education,[45, 54, 94-135] human development,[77, 78] and business.[38, 79-92]

Indicative of this relatively small body of scholarly literature on scholarly systems thinking, there are only 102 journal articles with systems thinking in the title that have been cited one or more times. A small number of these constitute empirical research on systems thinking. One might argue that, because systems thinking is not "a science," as has been proposed here, there is no need for empirical research about it. Of course, it is possible and useful to develop scientific knowledge about how people use systems thinking, where they might have difficulties understanding systems, and the like. In addition, much of this scholarly work on systems thinking has occurred in silos such as the field of systems dynamics or systems biology, thus ignoring a rich history, breadth, and scope of systems thinking that dates back before the term was formally used. Especially in light of the vast literature sources in systems science and the burgeoning popular literature on systems thinking, there is a surprising lack of scholarly work on systems thinking. More is needed.

One of the primary characteristics of the scholarly literature on systems thinking is that authors (in particular Richmond, Senge, Capra, Hammond, Bertalanffy, Sterman, and Checkland) propose that systems thinking is synonymous with a "special" model of some kind (usually the author's special model). The term "special model," used herein, refers to an instance of systems thinking that serves a specialized purpose or is born of a specialized field, but that is not representative of the larger, general scope and breadth of systems thinking. The term is used in contrast to a general model that, for example, would apply to all types of systems thinking regardless of the specialized application, field, or discipline. The tendency for some scholars to present their special models as synonymous with systems thinking is a disturbing trend. Most of these special models represent just one or a few nodes in Schwarz's map and therefore exclude large and important areas of knowledge-about-systems that contribute to systems thinking. These scholars also define systems thinking as either a portion of, or synonymous with, their respective fields, thereby ignoring the work of the many other streams of systemic thought represented in Schwarz's map or Francois's *Encyclopedia*. In addition, each purveyor of a special model presents his or her model as systems thinking, and as such tends to exclude components or ideas from other authors or disciplines. Furthermore, in describing each of these models, each "arbiter" presents his or her model as *the* model of systems thinking; there is little if any building upon each other's work across the specialized sub-fields of systems thinking. Thus, these scholars tend to work in isolated silos, often even unaware of each others' work or the models others have proposed.

In summary, Midgley, Francois, and Schwarz give us a compendium, an encyclopedic summary, and a visual map, respectively, of the vast number of ideas, fields, disciplines, and scholars that are involved in knowledge-about-systems. In the much smaller but still large popular systems thinking domain, the work of authors such as Senge and Wheatley indicates the promise of systems thinking in public practice but also forces us to face some of the pitfalls of popularized science. There is concern, for example, that aspects of systems thinking may be little more than a passing fad. McKelvey worries that one kind of systems thinking, complexity science, "'applied to management' [has] all the earmarks of becoming just another management consultant fad."[92]

Dynamics of the Literature.

Thus far, the discussion has focused on the structure of the systems literature. A heuristic is proposed that differentiates between two types of systems literature: knowledge-about-systems and systems thinking (both scholarly and popular). These two types of literature interact in dynamic ways.

For example, as was mentioned earlier, some scholars act as a "bridge" between these structures. Because systems concepts are so ubiquitous and multipurpose across disciplines, there is often confusion with the transmission and transfer of these concepts from one discipline to another. Through an analysis of both the structure and dynamics of the literature, the reader gains an understanding of the long history and vast terrain of systems concepts and the role that systems thinking plays within this terrain.

The relationships among the two structures are threefold: (1) knowledge-about-systems informs systems thinking, and as systems thinking gains more analytical sophistication, it can influence the development of knowledge-about-systems; (2) there are issues with the transfer of knowledge from one domain to the other that can be called “export effects”; and (3) there are issues with the transfer of knowledge from one domain to the other that can be called “context effects.” Export and context effects are a function of contextual changes that occur when knowledge is moved from one discipline to another. These analogical mappings are susceptible to misinterpretations of systems concepts and/or the situated uses of these concepts.

Understanding the potential feedback loop between knowledge-about-systems and systems thinking (Figure 2-4) helps us to understand this complex set of literatures.

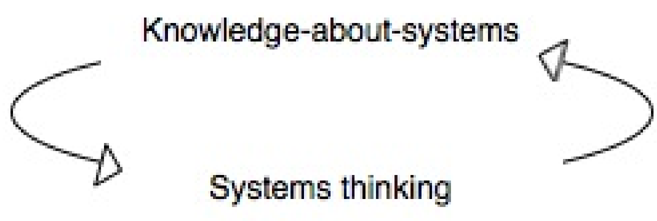


Figure 2.4: The Feedback Loop Between Knowledge-About-Systems and Systems Thinking

Currently, a relationship exists between knowledge-about-systems and systems thinking, but there is no explicit feedback from systems thinking to knowledge-about-systems. This lack of feedback may exist because systems thinking, while popular as a notion, has not yet been properly analyzed and studied in a sophisticated way. Analytical sophistication requires empirical research, theorizing, and formal learning as the result of implementation. If this sophistication occurs, then it is reasonable to predict that systems thinking frameworks will greatly influence the development of knowledge-about-systems by acting as schema upon which evolving patterns of thought can be consciously based. Increasing the sophistication of the systems thinking literature is the main thrust of the work herein. But, one might ask, haven't "systems scientists" gotten along just fine without a formally defined framework for systems thinking? Isn't it probable that these scientists will continue to contribute to the knowledgebase about systems without such a formal mental model? Ironically, it turns out that creating mental models based on patterns is central to advancing one's thinking. As Holland[93] points out, developing mental models allows for evolution. In general, as current processing is transformed into a mental model that allows for increased automation, new [mental] resources are made available to focus on novel problem solving. Specifically, as scientists think about systems, the patterns of this thinking can be better understood and transformed into a mental model. In this way, the explication of patterns of systemic thought and the formation of a mental model that formalizes these patterns occurs in feedback with new discoveries about systems. Furthermore, from an educational perspective, it is crucial that new scientists are not simply left to randomly develop such patterned thinking skills. These skills can be taught, thereby saving the scientist many years of developmental trial-and-error and freeing this time for further discoveries. Although systems thinking is a discretely different endeavor than thinking about systems, the two endeavors are dynamic and are related in feedback.

The relationship between the scientific pursuit of knowledge about different kinds of systems (e.g., ontological knowledge-about-systems) and the general, conceptual skills that underlie systems thinking is clear—systems scientists need systems thinking in order to think about their scientific work Yet, as society grows more complex; as individual action is more intimately tied to global effects; as economic, political, and social systems become increasingly interconnected; the need for systems thinking permeates nearly every sector of life, not just science. Everyone, it seems, may benefit from the ability to think in terms of systems. It is plausible that poets and politicians, baseball players and bar owners, students and scientists need an equal dose of systems thinking, but not necessarily of systems science.

For example, a recent job description for the President and CEO of the $90 million Casey Family Foundation includes “systems thinking” as one of the “essential skills” required of candidates.[94] Similarly, there is a call for systems thinking in practical fields such as business, education, and public health. The popular literature—books such as those written by Wheatley, Senge, and Capra—indicates the popularity of systems thinking in many arenas outside of the sciences, whereas knowledge-about-systems is traditionally created inside of the sciences.

As noted above, knowledge-about-systems informs systems thinking, but systems thinking can, in turn, inform knowledge-about-systems. What would systems thinking be if it were not for knowledge-about-systems? The attraction to systems thinking is borne of the successes of knowledge-about-systems in solving problems in new ways and in providing new perspectives of the universe and how it works. Therefore, while systems thinking is qualitatively different from knowledge-about-systems, it is also dependent upon it. There would be no systems thinking without the knowledge-about-systems. But is the converse also true? Educating people to develop a faculty for systems thinking is important for Presidents, policy makers, and practitioners in all fields. For example, the scientists of the future will need to approach problems differently, and systems thinking is one way to develop the minds of young scientists. In order for this change in scientific approaches to occur, science educators in public schools, colleges, and universities must take on a leadership role in this change process. So, while systems sciences give us detailed examples of how systems behave from which can be derived general principles and patterns, systems thinking provides a general conceptual framework from which to approach new scientific problems. The relationship between systems sciences (e.g., knowledge-about-systems) and systems thinking is in constant mutually beneficial feedback.

When knowledge is transferred from one domain to another, that knowledge is often changed as the result of export effects. Sometimes those who developed the transferred knowledge perceive these changes as invalid. Many scientists, for example, complain that scientific theories or ideas are being bastardized, minimized, or misrepresented to the public. One is reminded of the existence of these export effects when considering the existence of endowed chairs such as the Charles Simonyi Professor of the Public Understanding of Science at Oxford University, currently held by Richard Dawkins. Dawkins is at the forefront of ensuring that scientific ideas are presented to the public accurately. Unfortunately, many of the most intriguing ideas of science (especially systems science) are exported to the public awareness or to the practical domain without proper regard for the accuracy or reliability of the original concept. Nobel Laureate,Murray Gell-Mann writes:

> It seems characteristic of the impact of scientific discovery on the literary world and on popular culture that certain items of vocabulary, interpreted vaguely or incorrectly, are often the principal survivors of the journey from technical publication to the popular magazine or paperback. Important qualifications and distinctions, and sometimes actual ideas themselves, tend to get lost along the way.[55(p10)]

A companion problem to misinterpreting the science (e.g., export effects) is re-contextualizing the science in such a way that the meaning dramatically changes from the original, but for a reasonable and meaningful purpose. These may be called context effects because the difference between the source and the target domain (in mapping a concept from one domain to another) is caused by contextual changes rather than by a misunderstanding or misrepresentation of the original source. For example, scientists may feel that their ideas have been misinterpreted when in fact they have been re-contextualized within a domain that necessarily alters the original concept.

The degree to which these export effects are of concern is a function of context effects because the change in the concept may be solely due to its exportation, or it may be purposefully driven by the requirements of the new context. For example, while some scientists complain that the popular metaphors and analogies of chaos theory are wrong-headed, practitioners and non-scientists counter that pragmatics warrant a level of detail that satisfies the terms of its use. This is reminiscent of Herbert Simon's idea of "satisficing"; as is often and paradoxically the case in evolutionary systems, satisfactory is just perfect for the job. Scientists use powerful technical terminology with great precision because they need to, whereas practitioners may only require a much blunter version of the tool.

An example of both export and context effects is the science-to-public transfer of chaos theory. Many non-scientists have "latched on" to the concept of chaos, likely because the term corresponds with some of what they feel at home or work but also because popular accounts of chaos have captured their imagination. Yet, a scientist might think that the idea is being misinterpreted; that, for example, chaos theory refers to a very specific mathematical phenomenon, or that chaos is different from stochasticity (true randomness in the scientific vernacular). This example illustrates the need to account for both export and context effects. In one case, the public needs to be made aware of the important differentiation between chaotic and stochastic systems because the term "chaos" is being misunderstood in the public realm (export effect). At the same time, however, scientists need to be educated about the situational needs of the public regarding the concept of chaos. In the same way that one does not require the accuracy of an atomic clock to tell the time, one need not use a mathematical formula for chaos to utilize the concept of chaos in one's everyday life or work. Scientists must recognize these context effects not as misunderstandings, but as re-contextualized metaphors or analogical mappings that are appropriate to a particular situation.

These three dynamics of the literature—mutual feedback, export effects, and context-effects—are a reminder that the field that originates an idea is not superior to the field that applies the idea. They are instead complementary. First, knowledge-about-systems and systems thinking can co-inform each other (mutual feedback). Second, changes in meaning may be either perceived as invalid because of shifts in context from theoretical to practical domains or from one field to another, or such changes may actually be invalid regardless of this contextual shift (context effects). And third, the ideas may be exported for different reasons and to serve different purposes than they were originally designed to serve (export effects).

In summary, there are too many streams of ontological systems ideas to enumerate or to elaborate upon all of them; there are too many streams for adequate coverage. The vast literature on knowledge-about-systems informs scholarly and popular literature about systems thinking. In turn, as systems thinking becomes more sophisticated, it can inform advancing knowledge-about-systems. The dynamic relationship among these three varied knowledge bases is important because they are interdependent, and also because there are problems with export and context effects.

Summary

The systems literatures are vast and varied. These literatures include a loose ecology of systems concepts that can be divided into knowledge-about-systems and systems thinking. Systems thinking literature can be further divided into scholarly and popular varieties. These "distinct" literatures are not truly distinct, but overlap one another and are bounded by fuzzy heuristic borders. Each of these three literatures are part of a larger sea-change in human thought. The dynamics of these literatures are important. The systems thinking literatures are both informed by and inform the knowledge-about-systems literature. Knowledge-about-systems literature acts akin to a resource mine from which many systems concepts are exported to applied, educational, and public arenas. It is important that the essential meanings of these systems constructs are not lost in this transfer of knowledge from one domain to another. It is also important to recognize that the transfer of knowledge from one domain to another often requires scalar changes or contextual shifts to make systems concepts useful and applicable. These positive contextual effects are different from the negative export effects. Systems thinking is not a science; it is a conceptual ability, an orientation, and a framework. However, systems thinking is informed by knowledge-about-systems. In turn, systems thinking is an educational goal for general and science education as well as adult education.

Chapter Three

Ambiguities in the Field of Systems Thinking

This chapter presents a critical review of some of the theoretical and conceptual ambiguities of the systems thinking construct. Implicit in this discussion is the notion that these ambiguities must be better understood and eventually resolved in order to properly implement systems thinking in practice. Four common claims that attempt to define systems thinking and that dominate the literature are reviewed. These claims are contrasted with what is known about real-world systems to see whether the claims can withstand critical analysis. Throughout the chapter, counterclaims that may better correspond with what is known about real systems are proposed. At the end of the chapter, a summary of these proposed counterclaims is provided. These proposals represent new perspectives and relationships that may contribute to an understanding of systems thinking in general and to fields that adopt it, such as public health, education, and others, in particular.

Many fields, including public health, may be considered “early adopters” of systems thinking. Early adoption has its benefits but also its pitfalls. One benefit, for example, is that early-adopting public health practitioners can participate in shaping the field of systems thinking. One pitfall is that as they try to solve their own complex problems, practitioners will need to juggle these with the many problems the field of systems thinking has not yet solved. Most of these problems have to do with construct ambiguities. As a result, the field of public health is susceptible to much of the same ambiguity and disorganization that currently characterizes the field of systems thinking. As practitioners are drawn to the hope and promise of systems thinking, their first objective is to identify it—that is, to understand what makes systems thinking different from other forms of thinking and to assess where the boundaries of the construct lie.

This problem of defining systems thinking and identifying its boundaries is not unique to public health. There are many early adopters of systems thinking, including management and leadership fields, business, the field of evaluation, geology and earth sciences, biology, engineering, and education. All of these fields face the same problem: as they attempt to resolve their own problems using systems thinking, they unknowingly join a new morass of problems. Therefore, it is up to those who study systems thinking to clarify the construct without rendering it less integral.

This section reviews some of the existing answers in the literature to the question, What is Systems Thinking? Scholars who attempt to answer this question engage in claims that take the form: “Systems Thinking is…[X claim].” Four of the most common claims are reviewed, and through critical analysis, four corresponding counterclaims are offered. Table 3.1 outlines the four claims, each summarizing a conceptual theme commonly found in the literature on systems thinking. One can view each of these themes as “arguments” for what systems thinking is or is not; note that each statement in Table 3.1 takes the form “Systems thinking is…”

Table 3.1: Common Construct Problems in the Systems Thinking Literature

Systems thinking is…	defined as [X claim], where [X claim] is some special model of systems thinking, the foundations of which are grounded in a particular specialized field.
Systems thinking is…	holistic. The focus is on the whole rather than the parts.
Systems thinking is…	thinking in which the whole is greater than the sum of its parts.
Systems thinking is…	methodological, scientific, practical, or best framed in biological, ecological or organic terms.

Selection Criteria

Many important problems in systems thinking warrant coverage. It is reasonable to ask, therefore, why these four problems in particular warrant special selection and coverage herein. There are three reasons: First, because there are many possible problems to choose from, and because no single publication can meaningfully address them all, one must be selective. Second, the four problems addressed herein were selected based on their contribution to the construct of systems thinking. In other words, because each of these problems corresponds to the form, "Systems thinking is…," coverage of each of these issues deals directly with the construct of systems thinking. Third, and perhaps most important, these four problem areas were chosen because they help to frame the dialogue around what a model of systems thinking would look like, what qualities it would possess, and how it might be constructed. A critical discourse around each of these problems sets the stage for a generative heuristic—or, eventually, a formal model—of systems thinking. Precisely why a model of systems thinking is so important will be covered in later chapters.

Special Disciplinary Models versus General Knowledge-About-Systems

Examples from many fields illustrate how practitioners are adopting the current construct ambiguities of systems thinking. The field of public health offers as good a cautionary tale as any, and the ambiguities that appear in the public health literature are generalizeable to other fields. Assembled in 2002, the first Initiative for the Study and Implementation of Systems (ISIS) meeting of interdisciplinary scholars, researchers, public health practitioners, and "systems thinkers" was convened to launch a new effort to better understand and implement systems thinking in public health. Many at the table thought they had a solid understanding of what systems thinking was. If asked, they might have replied, "Systems thinking is system dynamics." After a year of meetings, invited speakers, and research, the ISIS group had expanded its definition of systems thinking to include four areas: system dynamics, network analysis, knowledge management, and management science.[95] In the second year, the ISIS team began asking broad-based questions such as:

> How can the flow in both directions between research and practice be optimized? How can systems structure and function be best characterized to be useful to the public health community? Which approaches can be used for better understanding and optimization of networks? Through which strategies do information and knowledge become the currency for change?[13(p3)]

By the time ISIS had finished its work it had arrived at a much different conclusion from its original definition of systems thinking:

> The ISIS team concluded that systems thinking in public health cannot be encompassed by a single discipline or even a single approach to "systems thinking" (e.g., system dynamics); instead, it consists of a transdisciplinary integration of public health approaches that strive to understand and reconcile linear and nonlinear, qualitative and quantitative, and reductionist and holist thinking and methods into a federation of approaches to systems thinking and modeling.[13(p3)]

This developmental process—from perceiving systems thinking as a special model such as system dynamics to perceiving systems thinking in more pluralistic ways—is probably not unusual for those who seek to learn more about systems thinking. The process that these public health leaders experienced in the ISIS initiative likely mimics that which many individuals and other types of practitioners in business, education, and other fields experience. As one enters the systems thinking literature, one is typically introduced to certain types of systems thinking that are more popular than others or that have done a better job "marketing" themselves. This "disproportionate representation" can lead to a number of misconceptions and ambiguities about what systems thinking is.

As noted earlier, not all systems thinkers agree on what systems thinking is. It is also true that systems thinking is the subject of an ongoing conceptual struggle. This dissertation, in particular in pointing out the various ambiguities, will join this struggle rather than solve it.

One common argument in the scholarly and popular systems thinking literature is framed as follows: Systems thinking is defined as [X claim], where X claim is portrayed as a model whose foundations are grounded in a limited field of study (i.e., a "special" or "specialized" model). A number of scholars resort to this strategy in order to develop a working model of systems thinking. For example, systems theorist Fritjof Capra[33] has developed a systems thinking model he now calls "ecoliteracy" that is derived from ecological principles. Yet, not all knowledge-about-systems is ecological knowledge. Ludwig von Bertalanffy,[12, 32] the father of general systems theory (GST), thinks of systems thinking as synonymous with GST, yet GST is a biological and holistic theory of organization, and not all knowledge-about-systems is holistic or biological. In *The Science of Synthesis: Exploring the Social Implications of General Systems Theory*, Hammond[96, 97] follows Bertalanffy's lead when she explores systems thinking through profiles of five of the founders of General Systems Theory. Hammond's account covers a distinct era in systems thinking associated with a specific form of systems thinking (GST), and the formation of the Society for General Systems Research in 1954. However, Hammond's research accounts for only a handful of "nodes" in Schwarz's map and only a few of the brief 3,806 entries in Francois' encyclopedia. Hammond covers the activity of a select group of specialized systems thinkers during a period of roughly forty years, whereas, as noted earlier, the history of systems thought dates back at least 2,600 years to Lao Tsu. Ervin Laszlo, considered by some but not by others to be one of the foremost thinkers in systems philosophy, expands the domain of systems thinking to include physics, cosmology, biology, ecology, and cognitive science, but limits the knowledge-about-systems from these fields to that which is holistic. Yet, there is debate (covered later in this chapter) as to whether systems concepts must always be holistic. Checkland[98-105] offers Soft Systems Methodology (SSM) as a methodological model and uses the concepts of systems thinking and SSM interchangeably. Of course, not all knowledge-about-systems is qualitative (e.g., “soft”), nor is it methodologically based. Each of these examples demonstrates a similar pattern in the systems thinking literature: when defining the construct of systems thinking, scholars are prone to offer their special model as synonymous with systems thinking.

The relatively small but influential field of system dynamics (not to be confused with Newtonian dynamics or dynamical systems) uses a strategy similar to that of Capra, Laszlo, Hammond, and Bertalanffy. However, system dynamicists are often more vocal and explicit about their claims to systems thinking. Some systems dynamicists explicitly differentiate their style of systems thinking as the systems thinking, while others make less explicit claims by simply referring to system dynamics and systems thinking interchangeably or synonymously. Next, we will explore the claims of a few system dynamicists as examples of either implicit or explicit claims upon systems thinking.

Barry Richmond[106] is one of many systems thinkers who support the argument that systems thinking is a proprietary type of thinking. He states:

> What is Systems Thinking, and how does it relate to System Dynamics? Let me begin by briefly saying what Systems Thinking is not. Systems Thinking is not General Systems Theory, nor is it “Soft Systems” or Systems Analysis—though it shares elements in common with all of these. Furthermore, Systems Thinking is not the same thing as Chaos Theory, Dissipative Structures, Operations Research, Decision Analysis, or what control theorists mean when they say System Dynamics - though, again, there are similarities both in subject matter and aspects of the associated methodologies. Nor is Systems Thinking hexagrams, personal mastery, dialogue, or total quality. Understanding what Systems Thinking “is not” will help us to more fully appreciate what its essence is. I have taken, and will continue to take, the non-politically-correct position that “reaching out” to these other disciplines and approaches is not where we should be focusing our energies. This is not to say that these disciplines and approaches do not themselves have much to contribute! Nor is it to say that we should not celebrate the synergies, or avail ourselves of cross-fertilization opportunities, where these occur. What I do want to say is that we have something in what I will define as Systems

> Thinking that is quite unique, quite powerful, and quite broadly useful as a way of thinking and learning. It's also capable of being quite transparent—seamlessly leveraging the way we learn biology, manage our businesses, or run our personal lives. We need to concentrate on realizing the substantial untapped potential which has been sitting right there in front of us for so many years, before we devote much explicit attention to "reaching out." […] Systems Thinking is not quite the same thing as System Dynamics. However, the overlap is very substantial, and the differences are more in orientation and emphasis than in essence.[106]

Richmond attempts to create an "operational definition" of systems thinking by explaining first what it is not and then explaining that "systems thinking is not quite the same thing as System Dynamics."

In other publications (see below), Richmond is clearer on the point that systems thinking is very closely related to system dynamics; this, despite the fact that system dynamics cannot possibly represent anything more than a small correspondence to the vast literature on knowledge-about-systems. Richmond demonstrates his bias toward his own discipline when he argues that systems thinking is a direct extension of, and only of, his field of system dynamics. In doing so, Richmond ignores the significantly longer, broader, and richer history of systems thinkers. System dynamics, as one field belonging to systems sciences, contributes to what we know about systems, but Richmond's claims of "what systems thinking is not" are narrow in scope and ignore a large number of other legitimate systems approaches. When Richmond states that his view is not "politically correct" he refers to politics within the system dynamics community; there are some system dynamicists who see the value in "reaching out" to other systems disciplines, especially where the systems thinking construct is concerned. These scholars, however, are not explicit in their writing that the term systems thinking should be expanded.

Richmond cannot make a viable argument—informed by the literature and the long history of systems approaches—for the proprietary claims he makes as to the nature and origin of systems thinking. In addition, Richmond contradicts his own argument in *The "Thinking" in Systems Thinking*,[107] in which he explains that the "most important skills" [of systems thinking] are:

1. Dynamic Thinking
2. View from 10K meters Thinking
3. Systems-as-Cause Thinking
4. Operational Thinking
5. Closed-Loop Thinking
6. Nonlinear Thinking
7. Scientific Thinking[107(p9)]

The skills Richmond claims are important to systems thinking are very broad. They include, among other things, all of scientific, nonlinear, and dynamic thinking. "Dynamic thinking," for example, is either the midwife, or at least an outgrowth, of the large and influential field of dynamics that began with Newton's invention of the calculus in 1666;[63] dynamics itself is a field that contains nonlinear phenomenon in general and chaos theory in particular. Remember that earlier, in the context of excluding certain domains, Richmond claims that systems thinking is not chaos theory. Despite his inclusion of these large knowledge domains as important to systems thinking, Richmond joins the father of system dynamics, Jay Forrester, in a strange Venn diagramming exercise in which these very large areas of knowledge are either subsumed or ignored by the very small field of system dynamics. Richmond provides a Venn diagram (Figure 3.1) that illustrates how his "operational definition" of systems thinking is related to his field of system dynamics.

Richmond relates his Venn diagram to that of Forrester, the father of system dynamics. Note that Richmond's Venn diagram (Figure 3.1) is different from

Forrester's Venn diagram (Figure 3.2) in how systems thinking and system dynamics are related. However, their models are also both very similar in that they exclude the many other fields of study about systems that are contained in knowledge-about-systems:

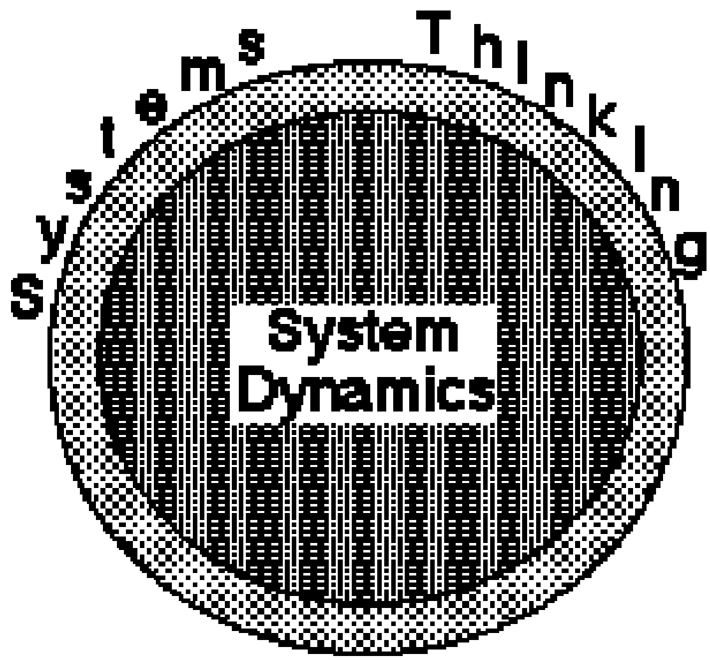


Figure 3.1: A Venn Diagram Representation of Richmond's View of the Relationship between System Dynamics and Systems Thinking[107]

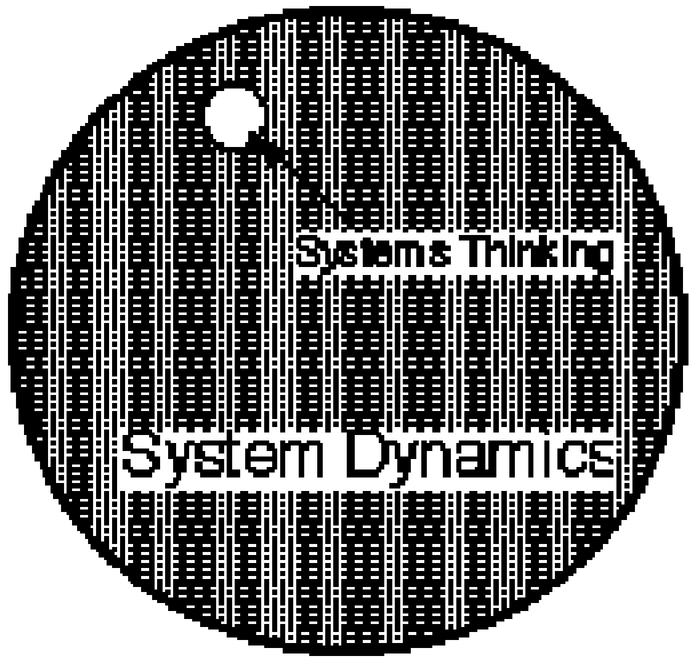


Figure 3.2: A Venn Diagram Representation of Forrester's View of the Relationship between System Dynamics and Systems Thinking[107]

Richmond differentiates between how he relates system dynamics and systems thinking and how Forrester views the relationship. But both versions are essentially the same in the context of knowledge-about-systems. In Figures 3.1 and 3.2, notice the real estate claimed by system dynamics in relation to systems thinking. While Richmond's definition of systems thinking is "wider in scope" than is Forrester's, it is still clear that Richmond views systems thinking as a thin "ring" around a much larger system dynamics. Yet, one of the essential skills Richmond assigns to systems thinking is "scientific thinking." How can this be? Does Richmond believe that the entirety of scientific thinking fits into the thin ring around system dynamics, while at the same time the relatively brief 44-year history of system dynamics that originated in 1961 with Forrester's Industrial Dynamics[79] fills the remaining 80% of the Venn diagram's real estate? It is clear that Richmond's claims as to the nature of systems thinking are inconsistent and that both Richmond's and Forrester's claims are incompatible with the long history and vast terrain of knowledge-about-systems. To be fair to Richmond and Forrester, other authors,[65-69, 106, 113, 143-148, 163-177] especially those associated with the field of system dynamics, share the same type of bias. These scholars have taken the position that system dynamics has a rightful and proprietary claim to systems thinking. Such a position is incompatible with the knowledge-about-systems literature as well as with viable and competing claims upon systems thinking such as those advanced by Capra, Bertalanffy, Checkland, and Laszlo. Each of these claims is necessary but insufficient to be a complete model of systems thinking.

Pulitzer Prize winner Will Durant writes, "What is thought? It baffles description because it includes everything through which it might be defined. It is the most immediate fact that we know, and the last mystery of our being. All other things come to us as its forms, and all human achievements find in it their source and their goal. Its appearance is the great turning point in the drama of evolution."[108(p8)] Durant explains that the scope of thinking is vast because it includes, "everything through which it might be defined."[108(p8)] Likewise, the previous discussion on knowledge-about-systems describes a similar situation regarding "systems"; the systems concept is so old and so broad that the term systems includes, as Durant says, "everything through which it can be defined." Systems thinking is the combination of these two ideas—systems and thinking—therefore it becomes increasingly clear that, in combination, systems thinking will be quite difficult to define. Some scholars have resorted to a simplified solution by restricting the domain of knowledge to which their special style of systems thinking corresponds. Of course, this "work around" strategy is useful, because it restricts the area in which one must focus to derive general conceptual principles that could be called systems thinking. It is natural for people to want to limit the scope of systems thinking in order to comprehend a small portion of it. At the same time, the resulting model of systems thinking can only claim to represent the portion of knowledge-about-systems to which it directly corresponds. It is not altogether odd that some systems thinkers have attempted to limit the conceptual scope of the construct of systems thinking, but while these model constructs are necessary they are not sufficient. Each of these scholars employs a similar strategy: if one limits the domain of knowledge-about-systems that applies to one's construct of systems thinking, then one's systems thinking model will be easier to construct. Easier yes, but still limited. These models of systems thinking are necessary to be sure, but they are not sufficient.

An alternative and broader construct is that systems thinking is any form of thought that "takes into account" knowledge about systems—that is, thinking that is informed by what is currently known about real systems (e.g., complex systems, biological systems, mechanistic systems, etc.). There are many types of systems, and for some of them system dynamics offers a powerful tool for discovery and understanding. But the other types of systems Richmond mentions (e.g., dissipative structures, chaos theory, etc.) also give the researcher powerful conceptual and methodological tools for understanding systems. The system dynamics community is one example of the tendency of some scholars to attempt to "own" or make "proprietary claims upon" systems thinking.

It is important to take a pluralist view within which the many rich traditions of systems thinking are included. This is particularly important to educators or organizational leaders who seek to develop systems thinking skills in students or employees. If the narrower argument is held, then the process of teaching and learning about systems thinking involves, for example, a course in system dynamics modeling and the thorough reading of *Business Dynamics*[86] or *Industrial Dynamics*.[79] However, if a broader view is taken—the view proposed in this dissertation—then teaching and learning about systems thinking involves educating students and employees in the many ways that varied systems work or, alternatively, seeking a model of systems thinking that is sufficiently pluralistic and integrative.

In light of these discrepancies of necessity and sufficiency, a different perspective is needed in which systems thinking is related to all of the various fields contained in knowledge-about-systems literature through an elemental-level conceptual relationship. This is surely an audacious task, but there is good reason to believe that the qualities that make systems ideas intuitively recognizable suggest that universal patterns or even elemental laws of systems thinking exist. Systems thinking is based on themes that are derived from knowledge-about-systems. A necessary and sufficient model of systems thinking must therefore be representative of knowledge-about-systems as a whole, or it must be identified as a special model of systems thinking that corresponds only to portions of the knowledge-about-systems literature. For example, it would be appropriate to describe the conceptual themes that are derived from system dynamics as "system dynamics thinking" or to describe the conceptual themes that are derived from the field of ecology as "ecological systems thinking," or the term Capra has recently and more accurately used in place of systems thinking, "ecological literacy." These are responsible uses of terminology that adequately describe the fields they relate to without ignoring the rich history that lies outside of these fields.

As students develop knowledge about how systems of all kinds are structured and how they function, they will also develop the skills of systems thinking. A pluralist view defines systems thinking in a way that is inclusive of the vast and rich traditions about systems from across the disciplines. Systems thinking is defined as thinking that is informed by knowledge-about-systems (of all kinds). In other words, systems thinking is not one kind of thinking, but rather is thinking that utilizes an understanding of many types of systems.

This definition is entirely accurate, but it has the unfortunate weakness of being nearly solipsistic—our definition for systems thinking becomes nothing more than everything that relates to knowledge-about-systems, which is useful in its accuracy but limited because of its broad scope. Yet, it is from this level of accuracy and careful constructivism that a concept of systems thinking must originate. The fact that this definition is excessively broad is problematic, but it is far less a problem than a definition that is obviously inaccurate or overly narrow. From a broad and accurate definition, albeit a solipsistic one, systems thinkers and researchers can develop sophisticated and useful models of systems thinking. In addition, this broadly defined construct of systems thinking does not preclude specialized types of systems thinking such as ecoliteracy or "systems dynamics thinking."

For the purpose of this dissertation, a pluralist, integrative, necessary, and sufficient ("PINS") construct of systems thinking will be used. However, as an educational goal, as will be covered in greater detail in Chapter 7, a "PINS" model of systems thinking is needed. Such a model would be derived from the PINS construct of systems thinking but would be of significantly more practical use.

In summary, many scholars propose special models (usually of their own making) and claim their model constitutes systems thinking. Currently, all models of systems thinking are situated in single or arbitrarily isolated fields such as system dynamics or ecology and are therefore in alignment with the systems concepts in their respective fields. These models are necessary, but not sufficient, for a definition of systems thinking. In contrast, any construct of systems thinking must be pluralistic, integrative, necessary, and sufficient. A PINS construct of systems thinking must be "thinking that is informed by or derived from knowledge-about-systems" (this is a <u>starting</u> point, <u>not</u> an <u>ending</u> point!). The benefits (accuracy) of a PINS construct outweigh the costs (solipsism). More important, establishing a PINS construct of systems thinking is the first step in eventually developing a PINS theory of systems thinking. A discrete PINS model of systems thinking will be both accurate and useful and can therefore minimize some of the negatives of a PINS construct. PINS offers a framework from which to begin considering what such a construct and model would look like by providing a "litmus test" that can be used to determine if the construct or model survives the test. The litmus test for a systems thinking construct or model must be its correspondence with knowledge-about-systems. A conflict with even the most anomalous features of knowledge-about-systems decreases the PINS value of the construct or model.

Holistic versus Part-Whole Balance, Boundary Bias, and Multiple Perspectives

Here again, where the adoption of ambiguities is concerned, public health offers a salient example that is generalizeable to many other fields that are currently adopting systems thinking. In the *AJPH* special issue on systems thinking, Editor Scott Leischow writes, "[Chong] noted that the delay between the articulation of general systems theory in the 1960's and the incorporation of those principles into modern systems biology was 'necessary, primarily to accumulate sufficient descriptions of the parts to enable a reasonable reassembly of the whole.'"[109(p404, citing 110(p1661))] Leischow is attempting to rectify an important misconception in the systems literature; that is, that systems thinking is holistic, or stated another way, that the focus of systems thinking is on the whole rather than the parts. This claim is common in the popular and scholarly literature on systems thinking that is influencing how systems thinking is being perceived and understood in public health and other professional fields.

A Google search of the exact phrase "systems thinking is holistic" returns 46 matches, while the search "'systems thinking' AND holistic" returns 89,100 matches. These simple searches of the "popularized" notion of systems thinking are confirmed by the topic and title of two of the most popular books on systems thinking, Lazlo's

The Systems View of the World: A Holistic Vision for Our Time,[52] and Jackson's popular business book, *Systems Thinking: Creative Holism for Managers*.[111]

Many scholars present holistic systems thinking as the answer to the problems of simple-minded reductionism (or atomism) that these scholars believe is not only a misguided epistemology but also a schoolyard "bully" among the sciences. Some scholars believe that reductionism (especially in its most extreme, linear, or simple-minded forms) is the dominant paradigm in the sciences and that it lauds its power over academe. To these scholars, holism is an opposing and liberating force to the intellectual oppression of reductionism. Bertalanffy, in particular, viewed holistic systems thinking as a kind of "hero" in the conflict—a hero who would rescue us from the oppressive regime of reductionism. To Bertalanffy, holism is nothing less than a war against the perils and powers of reductionism. Many scholars who are less adversarial than Bertalanffy also claim that "systems thinking" represents a new paradigm of holism; in particular, Fritjof Capra[2, 3, 33, 34, 36, 37, 70, 71, 73, 74, 112-116] and Ervin Laszlo.[52, 117-121] Capra writes:

> the first, and most general, criterion [for systems thinking] is the shift from the parts to the whole. Living systems are integrated wholes whose properties cannot be reduced to those of smaller parts. Their essential, or 'systemic,' properties are properties of the whole, which none of the parts have.[35(p36)]

Capra's views on systems, which he explains in several books and related works on the topic[2, 3, 33, 34, 36, 37, 70, 71, 73, 74, 112-116] form a claim that can be understood in one of two ways. The key distinction that must be analyzed in Capra's explanation of holistic systems thinking is the term "shift" [in focus] from the parts to the whole. Without its historical context, the phrase "shifting focus" can be grossly misinterpreted. "Shifting focus" could mean that systems thinking shifts some of the focus from the parts to the whole. The purpose of this shift is to rebalance a previous imbalance between reductionism (part focus) and holism (whole focus). An alternative reading of the phrase, and one that has been popularized, is that systems thinking shifts focus onto the whole and away from the parts. The focus is re-placed onto the whole. This interpretation does not recognize the historical context of this shift—a context that explains the shift itself as a part of a history of pendulum swinging between reductionism and holism. These two interpretations of Capra's and other similar claims about systems thinking will be referred to herein as the balancing and replacement interpretations, respectively.

The replacement interpretation is a gross misinterpretation of systems thinking. By Capra's own explanation of systems thinking, one must consider the "organizing relations" of the parts. In order to understand systems, one must understand their parts, how those parts relate, and how they behave. So, while systems thinking does "shift focus" from the parts to the whole, it does so to correct an imbalance. Thus it is a product of historical overemphasis on the particulate. Unfortunately, the more popular is the replacement interpretation,[33, 35, 52, 67, 107, 114, 115, 122, 123] in which systems thinking is perceived as a replacement of reductionism with holism.

Despite these claims to holism, it is unclear what such a claim means when applied to systems thinking. In a paper on the enablers, barriers, and precursors to systems thinking, Davidz[124] considers the conceptual problem of holism in systems thinking when he writes, "It is important to remember the embedded nature of systems. What is considered a holistic systems view is considered a reductionist view when the boundaries of the system are redrawn."[124(pp1–2)]

The claim of holism has two problems associated with it. The first is called, herein, the embeddedness problem, while the second is called the boundary problem. The embeddedness problem relates to the "embedded nature of systems"; if every whole is in turn part of a larger whole, then the claim of holism appears empty in relation to systems thinking. Systems thinking that is holistic is meaningless, precisely because wholes are embedded parts of larger wholes, ad infinitum. Clemens's[125] diagram in Figure 3.3 of systems and their corresponding knowledge domains illustrates the challenge of embeddedness for claims of holism. Note that if the claim that systems thinking is holistic holds true, then the only systems thinkers, according to Clemens's diagram, are cosmologists!

The embeddedness and boundary problems—both significant and related challenges to the claim of holism—are interrelated and are therefore difficult to disentangle. The extent to which a system exists is, in large part, a function of its boundaries. How are these boundaries drawn? Who, or what, decides which are internal parts and which entities are externalities of the system? The examples that follow illustrate these twin problems from different points of view. In each case, these examples provide significant challenges to the claims of holism in relation to systems thinking.

The question of systems boundaries is a definitional one. One of the defining characteristics of any system is its boundaries. A system's boundary differentiates between its internalities and externalities. The Oxford English Dictionary[126] offers one definition for systems. Yet, the nearly 900-word definition is so comprehensive that one must alternatively ask, what is not a system? In lieu of Oxford's definition, consider the following: there are approximately 193 official countries, 2,300 formal religions and/or ideologies, 20,000 disciplines and/or sub-disciplines of the arts and sciences, and countless individual concepts and ideas, and there are 6,314,000,000 people at last count, and countless other organisms on Earth. Can each of these be characterized as a system? To further explore the ideas of systems enclosure and embeddedness, consider the following true story.

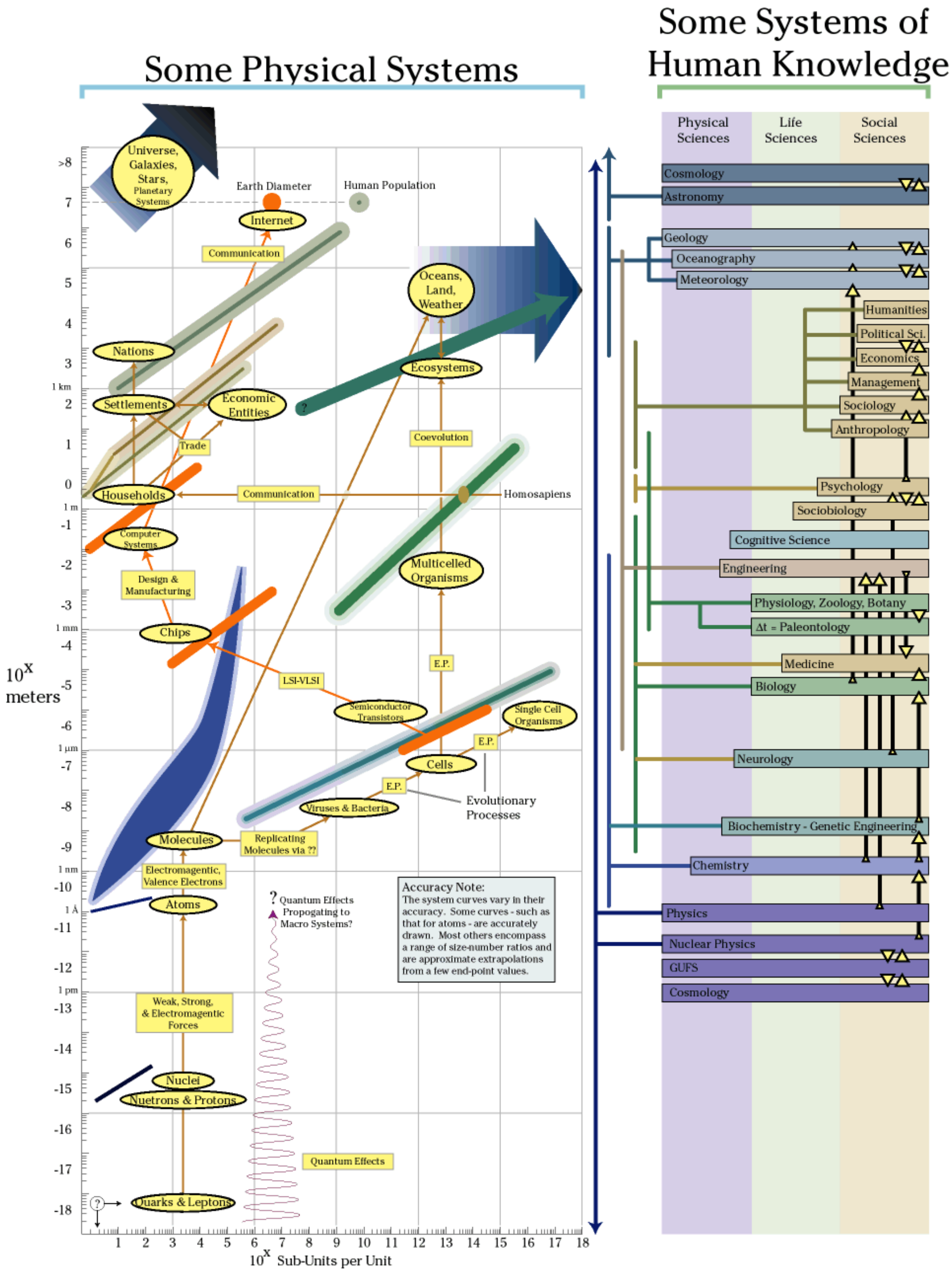


Figure 3.3: Clemen's Physical and Knowledge Systems[125]

In the early 1950s, the World Health Organization (WHO) launched "Operation Cat Drop" and dropped 14,000 cats on the island of Borneo. This strange scenario is often used as both an example of the perils of simple-minded reductionism and the triumphs of systems thinking, and also of the tendency for solutions to generate new problems. It is introduced here to provide a qualitative example that may provide some insight into what characterizes a systems view.[127, 128]

Imagine the following scenario. Dayak villagers on the island of Borneo are dying of the Bubonic plague. Seemingly unrelated to the problem, roof beams in the village are collapsing and a swarm of dead fish have washed up on the river banks. The plague is being caused by rats that transmit the disease to humans through bites. But why have the rats suddenly started biting humans? It turns out that the rats are migrating from the nearby jungle where they used to live. But why now? Why are there more rats in the village? Well, the cat population is declining, and the cats help to keep the village free of rats, both by killing the rats and by deterring them from living in the village. Normally, cats also chase geckos in the village, but usually they fail to catch the geckos, who move faster than the cats. But the average speed per gecko has decreased, and cats are catching and eating more geckos more often. But why are the geckos slowing down? Because they have been consuming a chemical called DDT, which doesn't kill them but makes them lethargic and slow. The chemical does, however, kill the cats when they eat the DDT-laced geckos. The geckos are ingesting the DDT when they eat cockroaches and caterpillars. As the cats eat more geckos, fewer geckos eat fewer caterpillars, and in turn, more caterpillars eat more roof beams, and more roof beams fall down. The fish washing up on the river banks, like the caterpillars and cockroaches, are absorbing DDT from the environment. So where is the DDT coming from? It was part of a DDT spraying program that WHO devised to kill mosquitoes, which spread malaria to the villagers. The threat of malaria, while significant, is far less than the threat of Bubonic plague, but when the decision to spray DDT was made, no one thought through the systemic and unintended consequences. After better understanding this village system, a new solution was devised. Fourteen thousand cats were airdropped on the village, and over a short time, they were able to decrease and/or disperse the rat population.

The Borneo story offers a compelling example of systems thinking and does a good job of differentiating systems thinking from the kind of simple-minded reductionism for which it is so often offered as a remedy. When presented with examples such as the Borneo problem, one gets a qualitative feel that a systems approach is not an empty imperative. There is a quality to a systems view that feels different than a non-systems view. Yet, it is difficult to pinpoint exactly what it is about this view that is so different.

Consider that the Borneo example includes several sub-systems, any one of which could be the sole analytical focus. Yet, in isolation, any one of these sub-systems fails to adequately explain the problem. In the Borneo example, the perception of closure occurs when the problems (plague, roof beams, dead fish) are related to various systems structures and to each other. Part of what makes the Borneo problem a good example of systems thinking is that there is closure when one arrives back at the beginning, with humans dying of malaria, as well as having explained some of the apparently unrelated mysteries such as rotting roof beams and dead fish. It is this qualitative perception of closure that may be responsible for what we deem, or do not deem, to be systems thinking. Yet, even the interrelated problems and variables of the Borneo example are incomplete. There must be thousands, even millions, of other meaningful interactions going on at the microbial, molecular, political, social, or even the climactic scale. Furthermore, it is easy to imagine that the entire Borneo scenario is just one node in a much wider global net. What, then, makes the Borneo example an example of systems thinking, when any of its various subsystems would not be? Are the qualifications for systems thinking merely a case of arbitrarily chosen closure? If so, the entire edifice of systems thinking is suspect because it is impossible to assess, in any objective way, what qualifies or does not qualify as systems thinking. In order to escape this untenable conflict in systems thinking, one must explore the issues of enclosure and embeddedness, which were introduced earlier in this chapter in greater depth.

Bertalanffy[12] explains open and closed systems as follows: "Conventional physics deals only with closed systems, i.e., systems which are considered to be isolated from their environment." He provides examples such as the second principle of thermodynamics which states, "in a closed system, a certain quantity, called entropy, must increase to a maximum, and eventually the process comes to a stop at a state of equilibrium." He continues, "However, we find systems which by their very nature and definition are not closed systems. Every living organism is essentially an open system. It maintains itself in a continuous inflow and outflow, a building up and breaking down of components, never being, so long as it is alive, in a state of chemical or thermodynamic equilibrium but maintained in a so-called steady state which is distinct from the latter." Bertalanffy describes what today in general terms is called a dissipative system. Bertalanffy differentiates between the physical laws guiding entropy in closed systems which lead to increasing disorder and evolutionary or biological laws guiding open systems toward "states of increased order and organization."[12(pp160–165)] Yet, despite Bertalanffy's distinction, it is unclear how an open system can ever be systematized in an objective way, at least conceptually, without creating at least a few arbitrarily chosen boundaries.

Thinking in general, and scientific thinking in particular, are constrained by local limits—they cannot be infinite. Therefore, one must place boundaries on any system under observation. Even where open systems are concerned, there must be, at least heuristically, some enclosure. Yet, it is unclear how this inevitably arbitrary closure allows for system thinking or even defining what a system is, or how a system at one scale is different than a smaller-scale system. In other words, what makes thought at one level systemic but at another level atomistic?

Consider the famous lecture by Richard Feynman in which he proposed that our "small" minds require conceptual boundaries:

> A poet once said, 'The whole universe is in a glass of wine.' We will probably never know in what sense he said that, for poets do not write to be understood. But it is true that if we look at a glass of wine closely enough we see the entire universe. There are the things of physics: the twisting liquid which evaporates depending on the wind and weather, the reflections in the glass, and our imagination adds the atoms. The glass is a distillation of the earth's rocks, and in its composition we see the secrets of the universe's age, and the evolution of the stars. What strange array of chemicals are in the wine? How did they come to be? There are the ferments, the enzymes, the substrates, and the products. There in wine is found the great generalization: all life is fermentation. Nobody can discover the chemistry of wine without discovering the cause of much disease. How vivid is the claret, pressing its existence into the consciousness that watches it! If in our small minds, for some convenience, we divide this glass of wine, this universe, into parts—physics, biology, geology, astronomy, psychology, and so on—remember that nature does not know it! So let us put it all back together, not forgetting ultimately what it is for. Let us give one more final pleasure: drink it and forget it all![129]

Even if one studies an open system and achieves balance in focusing on both parts and whole, it is not clear how thinking about a system becomes systems thinking. In other words, the systems thinking one is doing to study X is going to be considered reductionist or atomistic thinking by another researcher who studies Y, which includes, among other things, part X. If every part is itself a whole, how can we ever truly claim systems thinking?

The situation becomes even more complex when one considers the theory of computational equivalence, in which "all systems of sufficient complexity are equally complex."[130] If Wolfram is right, then any system of sufficient complexity—by which he means any system that appears complex, like a slime mold or a human or a society, but not like a rock—is equal in complexity to any other system. Wolfram's theory makes an important point: a scientist studying the eye of a fruit fly and a scientist studying the Amazonian rain forest may be studying two different systems that are equally complex. One is prone to incorrectly argue that the fruit fly's eye is part of the fruit fly system that, in turn, is part of the Amazonian ecosystem and, therefore, that the ecologist is more of a systems thinker than the entomologist.

The discussion thus far does not solve the problem that the boundary of a system is an inevitably arbitrary choice. Even if one balances part and whole thinking there remains something qualitatively mysterious—something difficult to pin down—about the nature of systems thinking. Given two examples—one of a systems thinker and one of a non-systems thinker—people are likely to be able to identify the systems thinker. But what is it about this systems thinker that they identify? If it is true that the observed whole is part of some larger system (and it always is), and therefore that, to an equal degree, the focus is on a part and the tendency is toward atomism, then what exactly makes something systems thinking? Clearly the balance between part and whole, rather than the focus on one or the other, is one answer to this question. One conclusion from the analysis of embeddedness is that systems thinking is balanced thinking. But what can we conclude from the discussion about enclosure? From the problem of embeddedness comes the problem of enclosure. Even open systems, in order to be thought about, require enclosure. Therefore, systems thinking must incorporate arbitrarily chosen, or at least artificial, boundaries. It is clear that any enclosure in an open system is an arbitrary or artificial boundary that creates internalities and externalities. Systems thinking can then be characterized as having a dispositional awareness of *boundary bias* and recognition of the externalities to the system. An awareness of this boundary bias—of the fact that all system perspectives draw relatively artificial boundaries in order to enclose systems—leads the systems thinker to situate the systems of thought within a context of externalities.

This need for enclosure and subsequent externalities cannot be remedied. Thinking cannot be infinite; this is especially so if thinking is to be at all practical. Therefore, systems thinking requires a "dispositional awareness" of the boundaries being drawn and the subsequent externalities and internalities that result. In addition, because there are multiple possible boundaries for any systems thought, this dispositional awareness must include a pivotal conceptual ability—perspective taking. Therefore, the claim of holism is opposed here with a tripartite claim that systems thinking is: (1) and/both, Odyssean, or middle way thinking that balances part/whole focus, (2) characterized by a dispositional awareness of boundary biases and externalities, and (3) characterized by multiple perspective taking.

Claims of holism in systems thinking are meaningless because of the embeddedness problem—every whole is a part of a larger whole, ad infinitum. Systems thinking is a focus neither on the part nor on the whole; it is thinking that balances focus between the part and the whole. The necessary condition of systems thinking, then, is to place the parts and the whole on an equal footing. Borrowing an idea from Collins and Porras,[131] systems thinking rejects the "tyranny of either/or" and embraces the "genius of and/both." Systems thinking is also a worldview that balances the roles of part and whole and focuses on complex interrelationships and patterns from multiple perspectives[132, 133]; it is an inherently transdisciplinary approach that blends many perspectives into something new; it has been portrayed as an Odyssean thinking style that combines both Appolonian and Dyonisian perspectives[55, 134]; and it is an epistemological stance that combines reductionist and holistic perspectives and bridges theory and practice. Systems thinking is balanced, Odyssean, or "middle way" thinking, meaning that it is dual-focused on part and whole while taking into account externalities caused by boundary bias and, in turn, taking multiple perspectives.

Greater than the Whole vs. Exactly Equal to the Whole

Once again, the field of public health is a good, generalizeable exemplar of the adoption in practice of existing ambiguities in the systems thinking literature. In what is effectively the dawn of a new chapter in systems thinking in public health—the opening paragraph of the editorial of a special issue on systems thinking in the *American Journal of Public Health*—Editor Scott Leischow writes:

> Many public health workers still regard this issue of the Journal, devoted to the theme of systems thinking and modeling, as a welcome affirmation that our endeavors to protect the public's health do indeed depend on *more than the sum of their parts*. [emphasis added] [109(p403)]

It is important to note that Leischow should not be held accountable for the metaphor of the whole being more than the sum of its parts. There are so many popular and reputable references to this idea in the systems fields that it would be surprising if these references did not trickle into the practitioner's understanding. As public health practitioners, scholars, and leaders develop a better understanding of systems thinking by engaging in the systems thinking literatures, they are also, in many cases, diving headlong into some of the misconceptions and ambiguities of the systems thinking field. It is a common claim in the systems thinking literatures—and now in the public health arena—that systems thinking is thinking in which the whole is more than the sum of its parts. This claim is offered in opposition to strict reductionism, that many scientists over many years can systematically divide a whole into pieces, like chopping up a human into bits, and analyze each part in great detail. In the end, it is assumed, each of the details of these parts can be summarized (added together) in order to understand the whole. Much of the literature in systems thinking and, in particular nonlinear sciences, uses the catch phrase, “the whole is more than the sum of its parts” to summarize the basic thrust of systems thinking. More recently, the concept of emergence has gained popular usage in both science and in the general public. This term is an outgrowth of and synonymous with the idea that the whole is more than the sum of its parts.

Lazlo[52] provides an explanation that helps to frame one of the core differences in systems views:

> Such widely dissimilar things as galaxies, organisms, and ecologies are now seen as so many varieties of systems: astronomical systems, biological systems, ecological systems, and so on. At first sight, this may appear to collapse the distinction between them: it seems to be reductionism in a new guise. Instead of reducing things to a concourse of atoms, as Democritus did, we now reduce them to the concept of systems. In fact, there is no such fallacy involved in systems thinking. To speak of systems per se is, of course, a simplification, but it is not a reductionist one. Whereas, traditional reductionism sought to find the commonality underlying diversity in reference to a shared substance, such as material atoms, contemporary systems theory seeks to find common features in terms of shared aspects of organization.[52(p10)]

Similarly, Capra states:

> They [systems] arise from the ‘organizing relations’ of the parts—that is, from a configuration of ordered relationships that is characteristic of that particular class of organisms, or systems. Systemic properties are destroyed when a system is dissected into isolated elements.[35(p36)]

Lazlo goes on to explain that parts of the whole are organized in some way, therefore the relationships and interrelationships that cause this organization are critically important. This notion is aligned with Capra’s explanation that focuses on relationships between parts. It is from this line of thinking—thinking about organizing relationships—that the popular moniker for systems thinking originates: the whole is more than the sum of its parts.

This widely cited phrase holds an important clue to the subtle nuances in the arguments between holism and reductionism. If one assumes that the parts are material, then it is clear that, as Capra argues, "systemic properties are destroyed when a system is dissected into isolated elements."[35(p36)] One cannot chop up a human or a car and merely add the material parts together to re-create a new whole, because lost in the dissection are dynamical relationships, structure, and organization that cannot be recovered. Yet this argument misses a critically important distinction: no tenet of reductionism inherently implies or explicitly states that the parts of a system must be material objects. Similarly, no tenet of reductionism inherently implies or explicitly states that the parts of a system could not be behavioral, inter-relational, or organizational. For example, it is conceptually valid to list the parts of a successful marriage as: 1) a spouse, 2) another spouse, and 3) love. Love may not be material, but it is part-and-parcel of a good marriage. Therefore, the often-used phrase "the whole is more than the sum of its parts" contains an implicit assumption that one is speaking only of material parts. When used to describe the notion of systems, this phrase can be a helpful beginning, but when it is used to imply that reductionism only deals with material parts, it is misleading. In short, there is nothing inherent in reductionism that implies material parts. In an interview with Capra, this researcher asked the following:

> CABRERA: So in that light, in terms of the whole being greater than its parts, is that true only if the parts are structural? In other words, if the parts are process-oriented, if you consider the parts to be process oriented or dynamical as well as structural, is it possible for a system to be more than its parts?
>
> CAPRA: Well, you could say that's artificial. The semantics here become very artificial because what we mean by part is a structure, not a process. And you can, loosely speaking you can say it's part of it, but you know, a relationship and a process is not usually what we mean by parts, and I think one thing that is very important, Maturana emphasized this always, is that in a living system, the network of relationships is a network of relationships between processes, not between structures. Although structures are involved, but relationships are relationships between processes, so that's very important.

Capra appears to view this line of reasoning to be semantic and artificial rather than meaningful. Yet, it may be that the reverse is the case; that it is semantic and artificial to assume that belonging (e.g., "parthood") is an exclusive club to which only structures may gain membership. Capra's argument seems to be based on a historical definition rather than on rationale—"what we mean by part is a structure, is not a process." Yet, one must ask, why do we interpret parts in this manner? What is our rationale? The "whole is more than the sum of its parts" is an influential metaphor for how systems could be perceived, and it belies the structural biases of current thinking paradigms. It is also the origin of another often-used term, "emergence." Like the popular moniker that acts as its origins, the notion of emergence is nonsensical. If the parts of a system are considered to be both structural/material and relational, then every whole is exactly equal to the sum of its parts, and emergence is a meaningless term in its current usage.

It should be noted that the phrase "the whole is more than the sum of its parts" is also used in a different way to differentiate between linear and nonlinear systems of equations. And, in this particular usage, there is a slightly different and more formal mathematical meaning. In his book *Sync,* Strogatz[49] writes:

> Linear equations are inherently modular. That is, a big, messy linear problem can always be broken into smaller, more manageable parts. Then each part can be solved separately, and all the little answers can be recombined to solve the bigger problem. So it's literally true that in a linear problem, the whole is exactly equal to the sum of the parts. The hitch, though, is that linear systems are incapable of rich behavior. The spread of infectious diseases, the intense coherence of a laser beam, the roiling motion of a turbulent fluid: All of these are governed by nonlinear equations. Whenever the whole is different from the sum of the parts—whenever there's cooperation or competition going on—the governing equations must be nonlinear.[49(p51)]

This popular phrase—more than the sum of the parts—dates back much farther, to the time of Aristotle. Bertalanffy writes that "in a certain sense it can be said that systems thinking is as old as European philosophy."[67(p407)] He points to Aristotle's worldview "with its holistic and teleological notions"[67(p407)] and to Aristotle's statement that, "the whole is greater than the sum of its parts," which Bertalanffy states is "a definition of the basic system problem which is still valid."[67(p407)] Although Aristotle is often quoted as having directly said the phrase, the actual quote reads:

> For it is not enough to say what are the stuffs out of which an animal is formed, to state, for instance, that it is made of fire or earth -- if we were discussing a couch or the like, we should try to determine its form rather than its matter (e.g. bronze or wood), or if not, we should give the matter of the whole. ... For the formal nature is of greater importance than the material nature…[135(p1045a)]

By "formal nature" Aristotle refers to the whole form (as in "form-al"), whereas "material nature" corresponds to the parts of material form (as in parts of material matter). Capra's claim that relational-parts are an artificial and semantic construct is similar to the way in which Aristotle has constructed the world. Aristotle proposes that the whole form is more than the material parts. Yet, there is no accounting for the relationships. Aristotle's view requires a metaphysical explanation such as emergence to explain how these parts magically assemble into a whole. An alternative construct in which parts are both structural and relational, however, requires no such metaphysics. It is a construct in which the whole is exactly equal to the sum of its structural and relational parts. No need for a "God of Emergence" nor any other metaphysical claims. It is precisely because of this confusion that systems thinking has been criticized as soft or metaphysical. This confusion may, in fact, be related to Aristotle's original thinking in the *Metaphysics*.

Bertalanffy links systems thinking to Aristotle's metaphysical origins when he states, "the problems with which we are nowadays concerned under the term 'system' were not 'born yesterday' out of the current questions of mathematics, science, and technology. Rather, they are a contemporary expression of perennial problems which have been recognized for centuries and discussed in the language available at the time."[67(p408)] Bertalanffy believes that the Scientific Revolution of the sixteenth and seventeenth centuries "replaced the descriptive-metaphysical view of the universe" (e.g., Aristotle's) with the "mathematical-positivistic or Galilean conception."[67(p408)] Bertalanffy proposes that this positivistic view neglected some of the important concerns and problems of the metaphysical view.

This line of thinking may account for one of the criticisms that modern systems thinking is soft or metaphysical. The misconception is that systems thinking lacks scientific rigor.[136] This fallacy can not only be traced to Aristotle's "metaphysics," a term that has a different meaning today, but also likely stems from popular literature that portrays systems thinking as "soft" or in some way in opposition to scientific or analytical thinking. Bertalanffy writes that systems epistemology "shares the same scientific attitude."[67(p409)] Systems thinking does emphasize holistic thinking,[67, 137-139] but it is not a rejection of the foundations of scientific thinking. Systems thinking is rooted in Aristotelian metaphysics of the whole (not current-day metaphysics), but it is also firmly rooted in mathematics and the physical and biological sciences, and represents some of the most rigorous and sophisticated work in the history of science.[136]

It could be said that 16th and 17th century science was not ready for a systems view, whereas we are now more able to approach systems problems scientifically. Either way, the artificial construct that parts must only be structural requires the creation of metaphysical or mystical explanations for how these parts become such transcendent wholes. And it is this common claim of systems thinking that may be responsible for some of its reputation as soft. Yet, systems thinking need not resort to metaphysical explanations such as emergence, as long as parts need not be members of the “exclusive club of structure.” That is, the parts of a whole can be both structural (the car is made up of 6,000 parts) and relational (each of these parts has relational properties that are also part of the whole). A brief description of the field of dynamics helps to clarify the point.

“The second maxim of Descartes’ Discours de la Methode was to ‘break down every problem into as many separate simple elements as might be possible,’” and this is of course quite similar to Galileo’s “resolutive” method.[67(p409)] Bertalanffy correctly points out that this paradigm has been passed down to “modern laboratory work.” Furthermore, he correctly points out that:

> This method worked admirably well insofar as observed events were apt to be split into isolable causal claims, that is, relations between two or a few variables. It was at the root of the enormous success of physics and the consequent technology. But questions of many-variable problems always remained. This was the case even in the three-body problem of mechanics; the situation was aggravated when the organization of the living organism or even of the atom, beyond the simplest proton-electron system of hydrogen, was concerned.[67(p409)]

Strogatz provides a current-day description of what Bertalanffy is describing in Table 3.2.[63(p10)] Strogatz provides the table as a heuristic device for “classifying systems on the basis of their dynamics.”[63(p10)] Dynamics is a large field consisting of many ideas and subfields. Punctuating a long history of systems thinking is the theory of chaos in the field of dynamics (or dynamical systems).

Dynamics is sometimes used as synonymous with chaos or nonlinearity, although the latter are both parts of the field of dynamics. Whether a system settles into equilibrium, changes in cycles, or in even more complex ways, the common theme is change, and dynamics provides a language and methods for understanding these changes. The dynamics of systems lead to areas of study that have captured the imaginations of both mathematicians and the general public in the beautiful images of fractals and chaos. Chaos, in which “a deterministic system exhibits aperiodic behavior that depends sensitively on the initial conditions, thereby rendering long-term prediction impossible,"[63(p3)] is just one of the useful ideas of dynamics which have become popular in recent years. The point is simple: dynamics are relational, and the dynamics of a system are part-and-parcel of the whole.

Parts are not necessarily material or object-oriented; they may also be interrelational, organizational, and dynamic. Once this clarification is made, as it is suggested here, the moniker "the whole is more than the sum of its parts" and other metaphysical ideas of emergence become non-sense. No whole is equal to more than the sum of all of the phenomena (both functional and structural) it contains.

Table 3.2: Strogatz' Classification of Systems Based on Dynamics[63(p10)]

	Number of variables -->				
	n=1	**n=2**	**n≥3**	**n>>1**	**Continuum**
	Growth and decay, or equilibrium	*Oscillations*		*Collective phenomena*	*Waves and patterns*
	Exponential growth	Linear oscillator	Civil engineering, structures	Coupled harmonic oscillators	Elasticity
Linear	RC circuit	Mass and spring		Solid-state physics	Wave functions
Nonlinearity -->	Radioactive decay	RLC circuit	Electrical engineering	Molecular dynamics	Electromagnetism (Maxwell)
		2-body problem (Kepler, Newton)		Equilibrium statistical mechanics	Quantum mechanics (Schodinger, Heisenberg, Dirac) Heat and Diffusion Acoustics Viscous fluids
			The Frontier *Chaos*		*Spatio-temporal complexity*
	Fixed points	Pendulum	Strange attractors (Lorenz)	Coupled nonlinear oscillators	Nonlinear waves (shocks, solitons)
	Bifurcations Overdamped systems, relaxational dynamics	Anharmonic oscillators Limit cycles	3-body problem (Poincare) Chemical kinetics	Lasers, nonlinear optics Nonequilibrium statistical mechanics	Plasmas Earthquakes
Nonlinear	Logistic equation for single species	Biological oscillators (neurons, heart cells)	Iterated maps (Feigenbaum)	Nonlinear solid-state physics (semiconductors)	General relativity (Einstein)
		Predator-prey cycles Nonlinear electronics (van der Pol, Josephson)	Fractals (Mandelbrot) Forced nonlinear oscillators (Levinson, Smale)	Josephson arrays Heart cell synchronization	Quantum field theory Reaction-diffusion, biological and chemical waves
			Practical uses of chaos Quantum chaos?	Neural networks	Fibrillation
				Immune system Ecosystems Economics	Epilepsey Turbulent fluids (Navier-Stokes) Life

It should be noted that there are several uses of the term “emergence” and of the related phrase that states that “the whole is more than the sum of its parts.” Not all of these uses are problematic, and not all of them mean the same thing. For example, it is possible to identify four distinctly different uses of the terms: (1) colloquial or dictionary usage, (2) nonlinear dynamics usage, (3) complex adaptive systems usage, (4) mystical and metaphysical usage. The colloquial or dictionary usage for emergence is not problematic because it simply uses the term in its traditional meanings, such as: to emerge from, to appear, to come out of, to arise from, or to come from a place one can’t see into a place one can see. The second type of usage—that of nonlinear dynamicists and mathematicians—is also not problematic unless these refined and narrowly defined definitions are taken out of context and used to support erroneous conclusions. For example, when a nonlinear dynamicist explains that “the whole is more than the **sum** of its parts,” what is meant is that linear equations can literally be solved in parts and then the parts can be added. Nonlinear equations cannot. This usage is a very narrowly defined idea and not typically explained using the term “emergence,” but with the sister concept “more than the sum.” Again, there is very little problem with this narrow usage unless it is taken out of the mathematical context in which the term “sum” has a very specific definition having to do with “adding.” The third definition of emergence is used by complexity scientists to mean that complex patterns form from simpler rules. In one sense, this rendition of emergence has to do with surprising outputs of a system (a black box) that are unattributable to the inputs. These surprising phenomena are determined to be “emergent,” but more is meant by this use of the term than merely “coming out of.” Instead, there is a sense that something mysterious is occurring, usually the result of causal relations across scale and/or control or conscious in relation to the goals or purpose of a system. The complexity version of emergence, in and of itself, is not problematic. That is, some in this arena are simply using the colloquial or dictionary definition or are referring to the nonlinear dynamical description. Yet there are those who use the term with more mysterious implications. The idea that a termite colony made up of “dumb” agents can collectively create a termite skyscraper (a classical real-life example) is thought to be emergent. One can see the obvious implications of causality across scale, control, consciousness, goals, and purpose. These three uses are not, in and of themselves, inherently problematic (unless the non-material emergence is implied). What becomes problematic is when these terms are exported to the public sphere or to the less technical disciplines, where the meaning of these terms becomes altered. Consider the following quote from a mystical website that uses emergence as a central theory:

> The theory of *Quantum-Integral Medicine* blends the newer sciences - quantum theory, complexity theory, and the **theory of emergence** - with spirituality, in order to create a framework for understanding the mechanism of the innate healing system and the capacity for human potential. The practice of Quantum-Integral Medicine shows people how to apply the theory to their lives, by the use of multimodal approaches.[140]

This type of usage, and variations on the uses explained above, are dangerous because they contain implicit metaphors that lead us astray as to how actual systems behave. The following metaphors are examples of some of the underlying messages in emergence:

- The Metaphor of Conscious Control
- The Metaphor of Purpose
- The Metaphor of “Something Extra”
- The Metaphor of Transcendence
- The Metaphor of Irreducibility
- The Metaphor of Mystery
- The Dominance of Structures over Relations

Some will argue that the emergence debate is merely semantics, and there are portions of this debate that are semantic. However, consider that many of these metaphors are the central arguments for misinformed movements such as intelligent design (e.g., irreducible complexity). None of these metaphors is new; they are merely wearing new clothing. Each of the mis-uses of emergence resemble the anti-materialism and mysticism of theology (e.g., transcendence, mystery, purpose, "more-ness" or something out there or in there (vitalism)). Therefore, while many aspects of the debate may be semantic, other aspects are meaningful and important. Emergence is to science what "context" is to the social sciences: a convenient "black box" upon which we blame all that yet unknown. One wonders whether the need to continually revisit and revive such notions rests in our own hubris; that is, in an inability to accept that there is a great deal that we do not yet know. There are surely many genuine scientists who use the term "emergence" to describe important phenomena. However, it is also a petri dish for the growth of public and scientific misunderstanding. It is important to ask whether these underlying metaphors are helpful or harmful to a public understanding of science.

Yet, the emergence debate is a hotly contested battle. A great deal of complexification accompanies these arguments for emergence, as does a great deal of hand waving. However, no matter how complicated the explanation and no matter how aggressive the hand waving, emergentists need to answer whether or not there is a [hypothetically] knowable and material causal chain or web that relates point A to point B. If their answer is "no," then emergence is a metaphysical term. If their answer is "yes," then emergence is no different from any one or several of the following ten synonyms:

1. "I have too much hubris to admit to not knowing everything so I need a placeholder that means the same thing as 'I don't know everything yet'"

2. “We don’t know” or “We don’t have the tools or technology to know, yet.”
3. “Because we know so very little, it *appears* as a mystery to us”
4. “Many important things occur as a result of stuff we don’t see and/or can’t ‘hold’ in our hands”
5. “Scale matters”
6. “A complex web of causes and effects”
7. Organization
8. Interrelations, dynamics, interactions, feedback
9. “No ***one*** is in control”
10. Error

Organic, Methodological, Scientific versus Conceptual or Best Fit

There are two distinct areas having to do with how systems thinking is defined and used in context that lead to ambiguity. These major ambiguities must be reconciled in order to un-muddy the definitional waters of systems thinking. The first ambiguity is that systems thinking is a set of methodologies, disciplines, sciences, fields, approaches, and/or theories. The second is that systems thinking implies that these methodologies, disciplines, sciences, fields, approaches, and/or theories are of a particular type; namely, that they are organic, ecological, or biological. Instead, it is suggested here that these definitional attributes of systems thinking cannot logically hold true. It is also suggested here that systems thinking is conceptual, that is, it is a set of “habits of mind.” It is further suggested here that systems thinking is not expressly organic, as there are surely any number of inorganic systems to which systems thinking might be appropriately applied. Of course, none of this is to say that there are not systems methodologies, systems disciplines, systems sciences, systems fields, systems approaches, and systems theories. Furthermore, there are countless organic, ecological, or biological systems of great interest.

Systems thinking is methodological, disciplinary, scientific, or theoretical versus conceptual.

Green[141] writes about the special issue of systems thinking in the *AJPH*:

> This issue of the journal offers examples and promise of an underutilized *methodology* and a *theoretical* approach to some of the complex problems of public health on which *other methodologies* and *disciplines* have foundered. A central question posed by this collection is whether systems approaches can fill the gap that is felt most acutely by public health as it strives to rise to the paradoxical challenge of evidence-based practice. [emphases added] [141(p406)]

Later, Green continues,

> To cast the challenge to systems science in historical public health context, I recall a similar plea by the late Edward S. Rogers, who had led the rebirth of ecological thinking in public health in the 1960s. He challenged sociology 37 years ago in his essay in Science, "Public Health Asks of Sociology . . ." to bring the theories and methods of sociology to the aid of a field that was faced with a growing need for social and behavioral sciences to cope with complexities of the newly emerging epidemics of chronic diseases. Today's plea to systems science has a strong echo of that early reaching out from public health.[141(p406)]

Green provides an excellent example of how public health practitioners and leaders are adopting some of the ambiguities that the field of systems thinking has yet to clarify. In doing so, public health joins a host of fields that are looking at "systems thinking" as a set of methodologies, disciplines, sciences, fields, approaches, and/or theories. Currently, the adoption of systems thinking that is occurring in public health is occurring in parallel in several other fields. The field of evaluation is one of these early adopters. In addition, evaluators are struggling with many of the same ambiguities and misconceptions as public health professionals as they attempt to sort out what systems thinking is. A recent evaluation email discussion list called "EVAL-SYS" debated, for nearly a month, many of the same terminologies that Green uses.

Here, too, the term "systems thinking" is used interchangeably to mean a set of methodologies, disciplines, sciences, fields, approaches, and/or theories.

In contrast, it is suggested here that systems thinking is <u>conceptual</u>. For example, it was mentioned above that a recent job description for the President and CEO of the $90 million Casey Family Foundation includes "systems thinking" as one of the "essential skills" required of candidates.[94] Common sense tells us that the Foundation is not looking for an expert in one or any particular methodologies, disciplines, sciences, fields, approaches, and/or theories. Instead, they seek a person who has developed certain "habits of mind." This distinction, between systems thinking being methodological, disciplinary, scientific, or theoretical and it being conceptual, is not a trivial one, especially for educators. Take, for example, the development of a course curriculum on systems thinking. If the curriculum designer believes that systems thinking is a set of methodologies, disciplines, sciences, fields, approaches, and/or theories, this belief will lead him or her down a very different path in curriculum design than if the designer perceives systems thinking as a set of conceptual "habits of mind." The latter will focus on meta-cognitive, cognitive, conceptual, and linguistic development of certain principals, whereas the former will be a summary course of various methods, scientific theories and discoveries, disciplines, and fields. Again, this is not to say that such a summary review of such methods and sciences would not be a very valuable undertaking, only that it should be clearly demarcated as knowledge-about-systems, not as systems thinking (the conceptual process).

The current state of affairs in public health is that practitioners seek to learn more about systems in general and in several different ways: they hope to learn more about systems methods such as soft systems methodology and concept mapping; they may want to learn about a particular systems field such as system dynamics; they seek greater knowledge of ontological systems in order to apply this knowledge directly or indirectly through analogies or metaphors; they seek to learn more about which fields of science constitute the set called "systems sciences"; they seek new approaches (methodological, scientific, conceptual or otherwise) that adhere to a systems orientation—e.g., systems approaches; they may also want to learn more about specific systems theories such as general systems theory, complexity theory, or chaos theory. When they specifically ask for systems thinking, however, we should be clear about what it constitutes so that they can be clearer in what they are asking for. Systems thinking is, by definition, conceptual.

Systems thinking is organic, ecological, or biological versus "Best Fit"

Orthogonal to the ambiguities above are those that present systems thinking as a set of methodologies, disciplines, sciences, fields, approaches, and/or theories that are expressly organic, ecological, or biological in nature. It is a common claim in the systems thinking literature that systems thinking is organic. This claim is predominantly the result of the influence of Bertalanffian ideas of systems thinking that were offered to refute mechanistic ideas. However, while the organic view is widely cited in the literature, it is not accepted by all systems thinkers. The idea that systems thinking is organic is particularly prevalent in the popular literature and the popular understanding of systems thinking.

Hammond writes, "Bertalanffy is generally acknowledged as the founder of GST," but also that "general systems theory is somewhat of a misnomer, since the term really refers to 'a way of thinking about' or 'an approach to studying' complex systems."[97(p22)] Today, likely because of the influence of the "general systems theory," it is difficult to decipher what general systems theory is. As Hammond explains, much of Bertalanffy's writing was general in nature, and nowhere in his book by the same name does he provide a concise description or equation for the "general systems theory.” Hammond writes that “the concept of an organism as an open system, introduced in 1940, is Bertalanffy’s most important contribution to the evolution of systems thinking, providing the basis for further work in nonequilibrium thermodynamics, most notably by Ilya Prigogine.”[97(p22)] Bertalanffy’s organism was the central character in his organismic view as an alternative to what was, at the time, and is to a lesser extent today, the supremacy and monopoly of logical positivism and reductionism in the sciences. Bertalanffy writes lucidly about his intention to shift the paradigm from a mechanistic to an organismic perspective. Robert Rosen, “a biologist who was influenced by Bertalanffy’s work, remarked, ‘Whereas I viewed the reductionisms and materialisms rampant in biology merely as scientifically inadequate, von Bertalanffy saw them as evil and dehumanizing; in the deepest sense immoral.’ In contrast, [Bertalanffy] saw the systems perspective, with its emphasis on relationship, as the basis of a new scientific paradigm that offered both science and humankind something better.”[97(p42)] Furthermore, while the passage of time has dampened Bertalanffy’s effect (it is presumed he would have wanted the pendulum to swing entirely to the organismic), the greatest influence of GST is the balancing power of its influence toward holism. In other words, while Bertalanffy may have seen the reductionisms of science to be evil, the forces of GST over the years have caused the pendulum to swing toward a more balanced approach rather than to swing fully toward a Bertalanffian holism.

Although it is unclear whether it is feasible to empirically confirm the broad influence of GST, it is likely that the rise of the contemporary biological metaphor, in opposition to the machine metaphor, was directly influenced by Bertalanffy and GST. There are two important paradigmatic, or epistemological, undercurrents that lead to the numerous metaphors that are used in attempts to explain, teach, and understand the sciences and the thinking of systems. In simple terms, the metaphors come in two flavors: systems as mechanistic or machine-like, and systems as biological or organismic. The metaphors of systems, along with the empirical science, should not be dismissed as they are indicative of the flavor of systems thinking that is being used. Furthermore, while there continues to be hand waving and academic tribal and territorial debates around these metaphors, it is true that both metaphors have been implemented with success. As the biological revolution increases its momentum, the machine metaphors are called into question. Yet, there are systems, even complex and nonlinear ones, that behave more like machines than like slime molds. There are also mixes of the metaphors, such as in bioengineering,[142] where cells are thought of as tiny biological machines, or in computing, where new "wetware" applications assume mechanistic and biological characteristics. The mechanistic frame is associated with positivism and reductionism, and it is argued that systems science "offers a way of going beyond the limits of reductionism, because it understands that much of the world is not machine-like and comprehensible through a cataloguing of its parts; but consists instead mostly of organic and holistic systems that are difficult to comprehend by traditional scientific analysis."[143(p7)]

Even today, as GST has become dispersed throughout our conceptual landscape, one can notice the subtle influences, like the common features passed down from generations that one sees in the faces of siblings. Different flavors of systems thinking can be characterized as a kind of genetic code that connects the generations of ideas as mechanistic, biological, or both. The field of system dynamics, for example, treats many systems as circuitry, bathtubs, or machines. This is not always the case, of course, and there are many concepts in system dynamics that could be construed as biological. However, it is difficult to deny that when looking, for example, at a system dynamics model, that lurking beneath the surface, in the minds of the creators, are mechanistic metaphors that help them to structure their work. The symbols used in system dynamics modeling, for example, are of "stocks" that are essentially bathtubs and "flows" which have little images of "valves" on them. These valves are ruled by "rates" and influenced by "controllers." Contrast these visual representations (from software packages such as VenSim® and Stella®) with the graphical elements of choice of complex systems (e.g., software such as Swarm, NetLogo™, StarLogo™, or AgentSheets®). In the latter, the graphical elements of choice are abstract "turtles," "termites," or "ants," and the environments they "behave" in are called "patches" (as in patches of ground or environment). The metaphors used in this area include commands such as "see," "find," "search," and "ask." While these modeling packages, and the systems sciences they belong to, are not directly related to GST, it is clear that the lasting influence of GST, which has permeated a number of systems fields, is the biological or organismic metaphor. These models and approaches, as contemporary manifestations of systems thinking, encode their phylogenic and morphological histories. The organismic paradigm has permeated many of the systems sciences and systems thinking as a whole.

Bertalanffy offers the organismic view in opposition to the mechanistic view as a way of dealing with the problems that arise when attempting to explain order and organization. Bertalanffy criticizes the two "principle ideas" that he claims were advanced by mechanists to deal with these problems. The first idea, according to Bertalanffy, is the analogy to man-made machines "epitomized by Descartes' bete machine" and later "expanded to the homme machine of Lamettrie."[67(p409)] The second idea that Bertalanffy claims was put forth is Darwin's theory of evolution that explains order and organization as "dealing with chance."[67(p409)]

One should be cautious, as Bertalanffy is not, in making too many claims as to the reason for the existence of the machine metaphor. Science, in many respects, is not the study of the universe, but the study of the universe that can be reasonably understood by current scientific methods. There are countless phenomena that exist, that are not yet understood, or understandable, by science. Bertalanffy points to Descartes'[144] second rule (mentioned above) but he does not cite Descartes' third rule, which states, "The third was to think in an orderly fashion 'when concerned with the truth,' beginning with the things which were simplest and easiest to understand, and gradually and by degrees reaching toward the more complex knowledge, even treating, as though ordered, materials which were not necessarily so."[144(p15)] As an aside, Descartes' first rule addressed his skepticism toward unfounded truth claims (e.g., bias and objectivity) and his fourth rule, essentially, was to be transparent or to "make enumerations so complete, and reviews so general, that I would be certain that nothing was omitted."[144(p11)] Descartes' rules are relevant here because although it is true that Descartes' thinking greatly influenced positivism and reductionism, there is no mechanical imperative to Descartes' thinking (although there may have been a mechanical flavor to his thinking; this could be explained by the time period in which he was writing). In the context of the historical period—and this is the case for any historically situated thinking—the machine metaphor may have represented the most advanced stages of thinking at the time. In other words, the machine metaphor may have evolved in popularity not merely because it had reductionist affiliations but because the most advanced and successful science of the day was mechanistic. Society parallels science in its use of metaphors, and the machine metaphor is as prevalent in the industrial revolution as it was in the domineering physics of the turn of the century. Corporations, for example, were understood as machines, and workers as cogs in a clockwork. Control of the machine would lead to efficiency. This type of thinking is often attributed to Descartes by systems or organismic thinkers.[37, 145]

Yet at that time in history, little about the human mind or about the biological processes was understood by the average citizen. It may be true that technological advances during this period were conscribed by the machine metaphor, but this may not be correlated with reductionism, only collocated with it. Reductionism merely requires that one take things apart to understand them, while holism contends that we must put them back together in order to understand them. Especially when the parts are reconstituted to be more than material structures (as discussed in the previous section), there is no inherent directive to reductionism that must reject the organismic view, or adopt the mechanistic view.

That science and society are moving toward the biological revolution does not mean that they must move away from reductionism, nor does it mean that in not moving away from reductionism they cannot embrace holism. Likewise, there is little use in "throwing the baby out with the bath water" by dismantling all mechanistically inclined approaches to systems thinking. If the system under observation is better served by a mechanical heuristic, then mechanistic metaphors and descriptions should be used, and vice versa for systems that are better characterized by organismic means.

The erroneous claims that systems thinking is biological or organic are reinforced by current developments in science and society:

> Prominent scientists, political leaders, and media representatives have proclaimed the 21st century to be the "Century of Biology."[146]
>
> Without question, the 20th century has been the epoch of biology—as measured by its advances, its total research support including that for practical areas such as medicine and agriculture, and its growing importance to our future.[147]

Today, as knowledge increases, both scientifically and socially, and as technology becomes more advanced, the machine metaphor has often, but not always, been replaced by biological metaphors. Yet, this may reflect the fact that we are in the midst of a biological revolution akin to the physical revolution of the 18th and 19th centuries. It is important to recognize the current day in context, however, and to learn from the misleading effects of bias toward local and recent events. There have always been "master metaphors" in science and society. In the pre-religious age, man's explanations of the world were based predominantly on the natural world. Evidence of this explanation can be seen in current-day tribes of the Philippines and Brazil who view the forest as a form of God. As the ideological basis for Taoism,[148] nature was the overarching metaphor for man's knowledge. Mayans worshiped the sun god. Even the childhood life of Abraham—the father of three of the world's most dominant religions—was influenced by pagan (natural) gods.[149] As religion began to dominate the ideologies of mankind, so too did religious metaphor. During the period of religious reign, it was believed that a pack of angels pushed the planets through their orbits. The logic of the Church, not the logic of nature, ruled man's thoughts and influenced his creation of knowledge.

Unseated by Galileo and Descartes, the religious metaphor was replaced with a grid and a clock. A Cartesian grid could overlay the universe and the fundamental properties of time and space. During this mechanical age, physics took on mechanistic overtones; the master metaphor for science was that of the clock.[37] Seeing knowledge as a mechanistic tool that meets a prescribed or adaptable purpose is fitting for such a mechanistic age. Yet, as society enters into the computational age (also called the information or digital age) and is influenced by the biological revolution, the metaphor will need to change again to meet and, to some extent lead, the times.

One can imagine that the future holds an even more potent metaphor than the biological one popular today; perhaps the metaphor of "consciousness" or some other term which today appears meaningless, soft, or unscientific. Moreover, one can reasonably expect that when this new metaphor takes shape, it will still be necessary to both take things apart and put them back together in order to gain a thorough understanding of them as well as the interrelationships, organization, and dynamics of systems. In this hypothetical future, it may be claimed, however, that a "systems view" is inherently biological and is therefore inadequate for dealing with the psycho-social domain.

Yet, a systems view need not be merely biological, in the same way that a reductionist view need not be merely mechanistic. These are terms that have been conflated and, unless one wants to dispense with the baby along with the bathwater, one should take care in differentiating them. Gell-Mann, speaking to an audience of some of the great systems scientists, states[55]:

> We all know that in most situations, theory has to advance along two tracks: the fundamental search for dynamical explanations on the one hand, and on the other, the phenomenological search for pattern in the laws of Nature. There are associated experimental domains in each case…There is always a reductionist bridge between these two kinds of explanation, the fundamental and the phenomenological. (I assume all of us are in principle reductionists.) But it often takes a very long time to construct such a bridge, such as the one between the brain and the mind, even though great strides are being made. While the construction is going on, it is necessary to pursue both approaches, which means in this case to study both the brain and the mind.[55(p8)]

In the same discussion, which inaugurates the founding of the Santa Fe Institute (SFI)—a premier institute for the study of complex systems—Gell-Mann offers the following testament to both forms of thinking—reductionist and holist:

> There are some psychologists and pop psychologists who like to place people on a scale running from Appolonian to Dionysian, where, roughly speaking, Appolonians tend to favor logic, rationality, and analysis, while Dionysians go in more for intuition, feeling, and synthesis. In the middle are those tortured souls, the Odysseans, who strive for the union of both styles. The new institute would have to recruit a number of Odysseans to be successful![55(p8)]

Of note, Gell-Mann won a Nobel Prize in physics in 1969 for his "contributions and discoveries concerning the classification of elementary particles and their interactions."[150]

The discussion thus far has pertained to the first of Bertalanffy's two "principle ideas," advanced to deal with order and organization; that is, with Descartes' *bete* machine and the influences of mechanistic-reductionist thinking. Now, the discussion will expand upon his second principle.

Bertalanffy presents the second principle that was advanced to deal with organization and order as "dealing with chance" and points to Darwin's theory of evolution.[67] He writes:

> The evolution of machines by events at random rather appears to be self-contradictory. Wristwatches and nylon stockings are not as a rule found in nature as products of chance processes, and certainly the mitochondrial 'machines' of enzymatic organization in even the simplest cell or nucleoprotein molecules are incomparably more complex than a watch or the simple strands which form synthetic fibers. 'Survival of the fittest' (or 'differential reproduction' in modern terminology) seems to lead to a circuitous argument. Self-maintaining systems must exist before they can enter into competition, which leaves systems with higher selective value or differential reproduction dominant. That self-maintenance, however, is the explicandum; it is not provided by the ordinary laws of physics. Rather, the second law of thermodynamics prescribes that ordered systems in which irreversible processes take place tend to move toward most probable states and, hence, toward destruction of existing order and ultimate decay.[67(p409)]

Darwin's use of the term "survival of the fittest" has been hotly debated and widely misunderstood. It does not mean, at least in the modern understanding, that organisms are dueling it out and that the strongest or biggest or most brutish organism wins and therefore survives. Raup[151] writes:

> The disturbing reality is that for none of the thousands of well-documented extinctions in the geologic past do we have a solid explanation of why the extinction occurred. We have many proposals in specific areas, of course: trilobites died out because of competition from newly evolved fish; dinosaurs were too big or too stupid; the antlers of Irish elk became too cumbersome. These are all plausible scenarios, but no matter how plausible, they cannot be shown to be true beyond reasonable doubt. Equally plausible alternative scenarios can be invented with ease, and none has predictive power in the sense that it can show a priori that a given species or anatomical type was

destined to go extinct. Sadly, the only evidence we have for the inferiority of victims of extinction is the fact of their extinction—a circular argument.[146(p17)]

Bertalanffy relates survival of the fittest to competition, yet Margulis and Sagan[152] explain, "the view of evolution as chronic bloody competition, a popular distortion of Darwin's notion of 'survival of the fittest,' dissolves before a new view of continual cooperation, strong interaction, and mutual dependence among life forms. Life did not take over the globe by combat, but by networking."[152(p240)]

Bertalanffy appeals to the machine metaphor when he states that "wristwatches and nylon stockings are not as a rule found in nature as products of chance processes." [67(p409)] First, Bertalanffy's use of the term "nature" is a nearly meaningless one. When a woodpecker builds its home, is the home part of "nature"? Or, when a chimpanzee designs and uses a tool to excavate termites from a hole, is it part of "nature"? Or, when ant colonies farm and enslave aphids, is it "nature"? Likewise, when humans build homes, design and use tools, or domesticate animals or plants, is it "nature"? The human tendency toward anthropomorphisms often leads to the conclusion that bird homes, chimp tools, and ant farming are part of nature, whereas human homes, tools, and domestication are not a part of nature. Bertalanffy suffers from this anthropomorphism when he implies that wristwatches and nylon stockings, because they are "man made," are not "found in nature." In a similar circuitous vein but relating to the domain of logic and thinking, Devlin[153] writes, "According to Aristotle, a proof, or rational argument, or logical argument, consists of a series of assertions, each one following logically from the previous ones in a series, according to some logical rules. Of course, this description can't be quite right, since it doesn't provide any means for the proof to begin: the first assertion in an argument cannot follow from any previous assertions, since in its case there are no previous assertions!"[153(p32)] Yet

James Burke, who traces the history of inventions and discoveries and the strange connections between ideas, writes[154]:

> Things almost never turn out as expected. When the telephone was invented, people thought it would only be used for broadcasting. Radio was intended for use exclusively onboard ships. A few decades ago, the head of IBM said America would never need more than four or five computers. Change almost always comes as a surprise because things don't happen in straight lines. Connections are made by accident.[154(p46)]

Therefore, the second portion of Bertalanffy's statement, that "wristwatches and nylon stockings are not as a rule found in nature as products of chance processes" is also a dubious claim. Many such "design inventions" are, in fact, products of chance processes.

In order to garner support for his own organismic view, Bertalanffy argues that the mechanistic metaphor is flawed, but he fails to provide adequate historical context, justification, or generalizeable examples to support his characterization of systems thinking as only organic. In fact, mechanistic systems exist, and there is a wealth of knowledge about these systems. Therefore, a scholar observing such a mechanistic system, using knowledge-about-systems, engages in systems thinking. Claims that systems thinking is only organic are unsupportable precisely because one can think of mechanical systems. These claims are also ignorant because they ignore the vast and rich knowledge that exists about systems of all kinds. For the purpose of this dissertation, the conceptual construct of systems thinking will be expanded to include both biological and mechanistic (and many other) metaphors, terminology, and characterizations. The common claim that "systems thinking is…organic" is challenged by a best-fit paradigm. Donald Campbell's best-fit approach—"methodological epistemological pragmatic eclecticism"—provides an appropriate analogy: the choice of systems metaphors, epistemologies, methods, or mindsets is practically oriented and should be selected based on whatever eclectic model has the greatest fitness for the job.

Each of the four ambiguities mentioned in this chapter represents areas in the systems thinking literature that may become challenges when practitioners adopt systems thinking and attempt to implement it. As practitioners from many fields visit the systems thinking literature, it behooves systems thinking scholars to represent the ideas with greater clarity and sophistication. New perspectives on these ambiguities are needed.

New Perspectives in the Field of Systems Thinking

The discussion thus far has reviewed the literature in systems thinking and the ambiguities that exist. From the discussion, a number of important definitional ambiguities arise. These ambiguities, and in some cases, misconceptions, are important because they are pervading the fabric of the practice and practitioner literature in various fields.

Centrally, there are four common claims that exist in the literature and that constitute an answer to the question, what is systems thinking? By providing counterclaims to these arguments that are supported by the literature one is able to construct a more pluralistic operational construct of systems thinking. Table 3.3 contrasts four common claims with the counter arguments that were developed from a critical review of the literature on systems thinking and were shown to have permeated other fields such as public health and education.

Table 3.3: Common Claim/Counter Claim Summaries

Theme	Common Claim	Counter Claim
Special Models versus Knowledge-about-systems	Systems thinking is [some specific model from a specific discipline]	Systems thinking is defined as thinking that is informed by knowledge-about-systems of all kinds. No model of systems thinking can contradict any anomaly in knowledge-about-systems
Holistic versus Part-Whole Balance, Boundary Bias and Multiple Perspectives	Systems thinking is holistic. The focus is on the whole rather than the parts.	Systems thinking: (1) is and/both, Odyssean, or middle way thinking that balances part/whole focus, (2) is characterized by a dispositional awareness of boundary biases and externalities, and (3) is characterized by multiple perspective taking.
Greater than the Whole vs. Exactly Equal to the Whole	Systems thinking is thinking in which the whole is more than the sum of its parts	The whole is greater than the sum of its parts if and only if, parts are defined as material. Systems thinking involves thinking about interrelationships, organization and dynamics of systems. [Or alternatively, parts are both structural and relational.]
Organic/Scientific versus Conceptual Best Fit	Systems thinking is methodological, scientific, etc. and is best framed in biological, ecological or organic terms.	Systems thinking is conceptual. The special system under question, observation, or application, not the popular epistemological flavor of the period, determines the terms that best frame the system.

For the purposes of this dissertation, the counter claims of systems thinking found in the right column in Table 3.3 constitute a construct of systems thinking that can be called “Pluralist Systems Thinking.” The pluralist view of systems thinking is used for the purposes of this dissertation.

Summary

The construct of systems thinking lacks clarity. Both the scholarly and the popular literature on systems thinking contain many claims about systems thinking, but in each case, these claims are insufficient to a construct of systems thinking. Four of the most common claims were countered through review and analysis of the literature: (1) Systems thinking is defined as thinking that is informed by knowledge-about-systems of all kinds. No model of systems thinking can contradict any anomaly in knowledge-about-systems; (2) Systems thinking is balanced thinking. It is both holist and reductionist. It is "Odyssean" thinking; (3) The whole is more than the sum of its parts if and only if, parts are defined as structural and not relational. This is an untenable position and an artificial categorization. Systems thinking involves thinking about interrelationships, organization, and dynamics of systems, and parts can be structural and/or relational; and (4) The special system under question, observation, or application, not the popular epistemological flavor of the period, should determine the metaphorical frame that best fits the system.

Each of these counterclaims is supported by the only possible arbiter of claims: the knowledge-about-systems-literature. The judge of sufficiency must be the knowledge-about-systems literature. If a systems thinking construct, claim, condition, or model contradicts even the tiniest fact in the knowledge-about-systems literature, then it cannot be sufficient. The need for a necessary and sufficient model of systems thinking directs our attention to pluralistic and integrative solutions based on the knowledge-about-systems literature. In short, a necessary and sufficient model must encompass the plurality of systems concepts and integrate them into a coherent whole. In this dissertation, we have called this type of model a PINS model of systems thinking—Pluralistic, Integrative, Necessary, and Sufficient. Until such time as a PINS model exists, the operational construct for systems thinking must be "thinking that is informed by knowledge-about-systems."

The point is simple: dynamics are relational, and the dynamics of a system are part-and-parcel of the whole. As is elucidated here in Chapter 3, the only current PINS solution to the construct of systems thinking is too broad: “systems thinking is thinking informed by knowledge-about-systems.” This may be the best current version of systems thinking, but it is hardly a handy one. The other counterclaims presented herein begin to remedy this problem by describing what systems thinking is and is not and provide a more sophisticated construct for systems thinking. A PINS model of systems thinking is needed for both construct and conceptual clarity as well as for practical pedagogical and andragogical applications.

Systems thinking is not a science, but it is influenced by and influences scientific thinking and progress. Systems thinking is not a particular methodology, but it influences and is influenced by various systems methods. Systems thinking is a conceptual framework, an orientation to the world, and a model for thinking about and learning about systems of all kinds—scientific, organizational, personal, and public. The application of systems thinking is therefore very broad. Because systems thinking is so broadly applicable to scientists and nonscientists, parents and Presidents, it is not merely a matter of science education. Systems thinking is the domain of general education, science education, and adult education.

Chapter Four

Literature Review of Systems Thinking in Public Health

The next sections review the literature on systems thinking from the narrower context of its application in one particular field—the field of public health. The application of systems thinking in the field of public health represents a "case" that is generalizeable to the many other fields currently attempting to apply systems thinking. The discussion thus far provides a backdrop for how systems thinking is being applied in these fields and, in particular, in the public health field.

Examination of the History of Systems Thinking in Public Health

The history of systems thinking is particularly muddied. Checkland explains:

> Although the history of thought reveals a number of holistic thinkers—Aristotle, Marx, Husserl among them—it was only in the 1950's that any version of holistic thinking became institutionalized. The kind of holistic thinking which then came to the fore, and was the concern of a newly created organization, was that which makes explicit use of the concept of 'system,' and today it is 'systems thinking' in its various forms which would be taken to be the very paradigm of thinking holistically.[98(pA3)]

On the history of systems thinking, Fritjof Capra in his Schrodinger lecture, explains:

> Let me begin my outline of the new understanding of life with a brief historical perspective on the tradition of systems thinking. Systems thinking emerged during the 1920s simultaneously in three different fields: organismic biology, gestalt psychology, and ecology. In all these fields scientists explored living systems, i.e. integrated wholes whose properties cannot be reduced to those of smaller parts.[72]

Deborah Hammond begins much further back in history with the Chinese book of change, the *I Ching*, tying systems thinking to its ontological roots in the study of "systemic things."[97]

Here again, it is sometimes difficult to extract the epistemological origins of systems thinking as a formal concept or field from its roots in thinking about ontological systems. The latter is surely a much older activity, dating to the dawn of the intellect. Midgley takes a more modest approach as a historian of systems thinking when he explains that it is impossible "to present a 'neutral' account of either systems thinking or its history."[16(pxix)]

While the roots of systems thinking are clearly very old, and while the origins of formal systems thinking are subject to much debate depending on one's perspective, the history of systems thinking in public health is relatively less complicated. Early examples of explicit attempts to connect systems (not specifically systems thinking) with health care exist. Burke[150] states that,

> Complexity theory appears to be a type of systems analysis, first applied to health care as early as 1938 by R.W. Revans who related concepts from physics to communication and information flow in a human system, including such ideas as noise and feedback loops. The description of the hospital as a human system by Revans is truly remarkable in its relevance to modern hospital epidemiology and its introduction of the concept of social learning in a self-directing and self-organizing system.[155(p2)]

There are many more examples up to the current day that explicitly apply systems concepts such as complexity or chaos to public health.[156, 157]

The earliest publication of the term "systems thinking" in public health literature appears to be in Huz.[158] In 2001, Chan published a paper in *Nursing Inquiry* entitled "Implications of organizational learning for nursing managers from the cultural, interpersonal and systems thinking perspectives."[159]

Lenaway[160] places the field in a similar timeframe:

> The relatively new field of public health systems research is related to, but distinct from, more well-established areas such as health services research. It has emerged within the last decade primarily because of the need to better understand how the level of development of national public health

> infrastructure and the multiplicity of organizational arrangements in public health affect health outcomes.[160(p410)]

Leischow[109(p404)] provides a succinct analysis (adapted from Chong[110]) of how these historical threads—the application of systems knowledge and the broader goal of systems thinking—can be woven together. He explains that the ability to think in systemic terms depends upon a sufficient accumulation of descriptions of the parts (e.g., ontological knowledge about public health systems). In light of this argument, the future of systems thinking in public health depends as much on how systems thinking evolves as a field as it does on the continued use of systems concepts and theories to develop better ontological descriptions of public health phenomena.

Examination of the State of the Field of Systems Thinking in Public Health

This section is an introduction to the literature in the field of systems thinking in public health. The history of systems thinking in public health is relatively short. Efforts to understand and implement systems thinking in public health are growing in popularity and promise. The current state of the field can be positively summarized as having vast potential, meeting with popular support, and providing hope for solutions that systems thinking promises to contribute to the public health endeavor. In contrast, it can be negatively summarized as being nascent, immature or even premature, ambiguous in its scope and value, and marked by skepticism or faddism. Whereas the field of systems thinking has traditionally been a conceptual and intellectual endeavor, the field of public health is, by definition, a professional and practical endeavor. Therefore, systems thinking in public health, in one important sense, serves as a bridge between theory and practice, and between the intellectual and pragmatic domains. On the one hand, there is a high degree of positive, popular, and hopeful support for systems thinking by public health professionals. These practitioners are overwhelmed with the complex task of improving public health, and systems thinking holds promise for cutting through this complexity so that they might more effectively manage the systems that lead to better public health. These practitioners have, in many cases, come to realize that the root crisis is in the way people think about problems and in turn, develop solutions that create unintended consequences. For those that view the way we think as being an underlying cause of many of the problems in public health, systems thinking, as a new way of thinking about problems, offers hope.

On the other hand, experienced public health practitioners have, more often than not, been a part of past initiatives in which promising "new paradigms" that require hard work to implement have turned out to be little more than passing fads in retrospect. Therefore, while the conceptual and intellectual ideas associated with systems thinking may be sound, the challenges to implementing it are a significant barrier to its use. Understanding these challenges will be critical to a more valid understanding of whether one should see potential and promise or be disappointed by a passing fad; be hopeful or skeptical; or invest in the work to surmount the challenges of implementation of systems thinking in public health or look for something else to guide implementation. Of course, this situation is compounded by the fact that the conceptual and intellectual ideas associated with systems thinking are not free of their own conflicts—chief among them being the field's inability to arrive at an accepted definition, construct, or framework for systems thinking.[141]

In support of the need for systems thinking in public health, numerous recent initiatives and publications have explicitly called to practitioners to incorporate systems thinking into their work. Among them are several influential publications, such as the Institute of Medicine's report entitled, *The Future of the Public Health's in the 21st Century*,[161] *The World Health Report 2000*,[162] *Crossing the Quality Chasm*,[163] and "Protecting health: a new research imperative"[164] in the *Journal of the Association of American Medicine*. Most recently, a special issue on systems thinking to be published in 2006 and currently pre-published on the Web by the premier journal in the field, the *American Journal of Public Health*, contains 30 editorial, commentary, and research articles on systems thinking in public health.

Gerberding,[164] the Director for the Centers of Disease Control and Prevention, writes,

> New insights and new innovations must be developed in the 3 domains of health protection research: preparedness for new and emerging threats; health promotion; and prevention of disease, injury, and disability. To do this requires reaching outside traditional boundaries to a much broader set of scientists, agencies, and sectors and requires fully engaging academics, partners, practitioners, and the public in the process. There are significant barriers to closing the science gap, most importantly underinvestment in areas such as translational research, prevention science, public health systems research, and the determinants of health and health disparities, as recently outlined by the Institute of Medicine.[164(p1404)]

In their editorial to the special issue on systems thinking in *AJPH,* Leischow and Milstein[109] comment on Gerberding's paper, "[Gerberding] named 'dynamic systems and syndemic approaches' as research imperatives for protecting health, even while acknowledging that applications of this science in the health arena are in their infancy."[109(p404)]

An influential report by the Institute of Medicine, entitled *The Future of the Public Health's in the 21st Century*, places systems thinking as one of 8 "Core Public Health Competencies"[161(p119)] citing the Council on Linkages between Academia and Public Health Practice as its source. These 8 Core Public Health Competencies include:

1. Analysis and assessment
2. Policy development and program planning
3. Communication
4. Cultural competency

5. Community dimensions of practice
6. Basic public health sciences
7. Financial planning and management
8. Leadership and systems thinking[161(p119)]

Macro-scale pronouncements such as this one, from the Institute of Medicine and the Council on Linkages between Academia and Public Health Practice, demonstrate support for the crucial role of systems thinking in public health; they also illustrate that systems thinking in public health is a research-to-practice endeavor marked by many of the same challenges that all such endeavors exhibit. The Council is "composed of leaders from national organizations representing the public health practice and academic communities. The council grew out of the Public Health Faculty/Agency Forum, which developed recommendations for improving the relevance of public health education to the demands of public health in the practice sector. The council and its partners have focused attention on the need for a public health practice research agenda."[161(p118)]

The World Health Report 2000,[162] *Health Systems: Improving Performance*, a publication of one leading public health agency, demonstrates the need for systems thinking without ever referring to the term itself. In the 160-page document, the term "systems," the framing idea, is used 322 times. Defining a health system, the report states, "In today's complex world, it can be difficult to say exactly what a health system is, what it consists of, and where it begins and ends. This report defines a health system to include all the activities whose primary purpose is to promote, restore or maintain health."[162(p4)] This definition, among other similar definitions found in the literature, illustrates some of the implicit challenges many practitioners face: the increasing complexity of their work; the difficulty in defining borders where systems and their influences begin and end, between what is inside, influential, and needs to be considered and what is not; and the need to think more broadly about the interconnected activities that increase the public's health and the interconnected maladies that lead to a decline of the public's health.

Another Institute of Medicine report, *Crossing the Quality Chasm: A New Health System for the 21st Century,*[161, 163(pp8–9)] frames health care as a system and offers 10 "simple rules to guide the redesign of the health care system."[161(pp8–9)] The language of "simple rules" is derivative of one flavor of systems thinking called complex systems. The report continues, "A health care system can be defined as a set of connected or interdependent parts or agents—including caregivers and patients—bound by a common purpose and acting on their knowledge. Health care is complex because of the great number of interconnections within and among small care systems."[163(p64)] An influential source in public health, Crossing the Quality Chasm explains "What is important is for the leader to understand how units relate to each other—a form of systems thinking—and to facilitate the transfer of learning across units and practices."[163(p138)]

Here again, several themes are implied. First, there is a feeling of hope, promise, and support for implementing a systems thinking perspective as a means of changing public health for the better. Second, the reason traditional thinking needs to change is that public health is increasingly complex, interconnected, and interdependent.

Among the examples in the literature, perhaps the most significant demonstration of support, hope, and potential for systems thinking in public health is a recently released special issue on systems thinking in the premier public health journal, the *American Journal of Public Health* (*AJPH*) (The research explained herein was included in this special issue). The *AJPH* website describes the journal:

> The American Journal of Public Health (AJPH) is the No. 1 publication dedicated to original work in research, research methods, and program evaluation in the field of public health. This prestigious journal also regularly publishes authoritative editorials and commentaries and serves as a forum for the analysis of health policy. The stated mission of the Journal is "to advance public health research, policy, practice, and education." All published papers have undergone rigorous peer review (only one out of five submitted papers is accepted for publication). Each month, the nation's most influential public health professionals turn to AJPH for the most current, authoritative, in-depth information in the field.[165]

The high quality of scholarship represented by *AJPH* publications and the intensive vetting of submissions makes even a single article on systems thinking in public health a reliable sign of its relevance to the field. An entire special issue dedicated to the topic, therefore, underscores the perceived relevance of systems thinking to the field of public health. To be sure, this special issue will be met with a large degree of support and will also stimulate debate and likely even controversy. The field of systems thinking in public health will benefit from more public dialogue as a result of this issue. Because the electronic pre-publication (in March 2006) of the issue is so recent, it is not possible to include what is likely to be a fascinating future dialogue about systems thinking herein. To a large extent, however, the dialogue has already begun in the pages of this special issue. One of the most obvious themes to come out of the special issue—a collection of different perspectives—is that many different views on systems thinking exist. These views, and some of the most relevant publications in this pre-publication, are presented in greater detail in Chapter Three.

Because systems thinking as applied to public health is inherently a research-to-practice endeavor, some practitioners have already begun implementation of systems thinking in their initiatives. These implementation initiatives are not only a valuable learning opportunity for practitioners; they are also fertile ground for researchers to learn more about the challenges associated with the implementation of systems thinking. Two initiatives in particular should be mentioned (there are no doubt others). The first is the Initiative for the Study and Implementation of Systems (ISIS) sponsored by the Division of Cancer Control and Population Science at the National Cancer Institute and administered by the Battelle Centers for Public Health Research and Evaluation. The proposal for ISIS was written in 2002 and was subsequently funded. The ISIS team of interdisciplinary research scientists and practitioners worked from 2002 until late in 2004, exploring the often-confusing landscape of systems thinking in search of important contributions that could be translated into public health such as "efforts to combat tobacco use, particularly in the face of countervailing forces such as the efforts of the tobacco industry."[13(p540)] Trochim et al.[13] summarize some of the realizations made by team members during the 2-year ISIS project:

> The ISIS team also recognized that the complexity and breadth of systems thinking may be dismissed as being too complicated. If the public health community, from clinicians to policymakers, is to value systems thinking as a guiding approach, it must be practical, manageable, and accessible. Toward that end, ISIS supported efforts that resulted in practical examples of systems ideas in public health contexts: development of a system dynamics model for characterizing the complex state of tobacco use and its control, creation of a map of the social network of tobacco control organizations, a concept mapping project to promote better understanding of how to integrate research and practice, and a knowledge management map to guide the use of information in tobacco control. In addition, ISIS supported actual networks for global tobacco research and reduction of harm from tobacco and produced a monograph summarizing the 2-year effort and serving as a road map for future approaches to systems thinking in public health.[13(p540)]

The ISIS monograph is in press (to be published as volume 20 in the monograph series of the National Cancer Institute, National Institutes of Health). Like the *AJPH* special issue, the ISIS monograph illustrates some of the most recent contributions to the field of public health and the focus of these publications on systems thinking. These seminal documents and practitioner initiatives point to the increasing state of awareness of systems thinking in public health. The ISIS initiative is an introductory exploration into systems thinking by public health practitioners and leaders.[166]

A second public health initiative that is exploring systems thinking is the Syndemics Prevention Network (SPN)[13(pp104–109)] and is supported by the Centers for Disease Control and Prevention. Trochim, et al.[13] write:

> [SPN] studies how recognition of mutually reinforcing health problems (substance abuse, violence, AIDS) expands the conceptual, methodological, and moral dimensions of public health work. This group seeks to learn how innovative ways of thinking about health as a system—along with the methodological techniques they inspire—lead to more effective and ethical action.[13(p541)]

Trochim et al.[13] cite other examples of public health initiatives that take systems thinking into account:

- The Community–University Partnerships Initiative sponsored by the W. K. Kellogg Foundation[167]
- The community-based participatory research efforts sponsored jointly by the Agency for Healthcare Research and Quality and the W. K. Kellogg Foundation[168]
- The Community–Campus Partnerships for Health[169]
- The efforts of the Institute for Healthcare Improvement[170]
- The Healthy Cities movement[171]
- The Partnership for the Public's Health[172]
- The Turning Point Program[173]
- The efforts of the World Health Organization's Commission on Social Determinants of Health[174]

The scholarly publications and practical initiatives mentioned above serve well to illustrate the current state of systems thinking in public health. In particular, they appear to illustrate that (1) the complexity of public health systems leads practitioners and researchers to look for new ways of thinking about and approaching problems; (2) systems thinking is perceived as a new paradigm that may fill the need for new types of thinking; (3) the application of systems thinking in public health is by definition a research-and-practice endeavor, that is, it requires the integration of research and practice; (4) although systems thinking is nascent in the field of public health there is hope, support, and perceived potential for it; and (5) awareness for systems thinking in public health is growing, moving from the margins into mainstream publications and into the awareness of leading public health researchers, practitioners, and agencies.

Of course, not all of the efforts in public health regarding systems thinking are hopeful, supportive, and pregnant with potential. There is also confusion, ambiguity, skepticism and fear of faddism. Because systems thinking is so new in the field of public health, there has been little published in the public health arena that directly criticizes the systems thinking view. It is likely, however, that this has more to do with its nascence than with a positive consensus on the subject and thus is not indicative of a lack of serious skepticism. As systems thinking becomes more visible, for example, as a result of the *AJPH* special issue and the ISIS monograph, one might reasonably predict more public debate, criticism, and skepticism. For example, in fields such as business and management, where systems thinking is only slightly more mature, concerns as to its value are more numerous. The fear that systems thinking is merely a new consultant's fad, in particular, is the source of one such debate. McKelvey[92(p5)] cites Merriam-Webster when he writes that a fad is "a practice or interest followed for a time with exaggerated zeal."[92(p5)] He continues, "management practice is especially susceptible to fads because of the pressure from managers for new approaches and the enthusiasm with which management consultants put untested organization science ideas into immediate practice."[92(p5)] Public health might be considered similarly susceptible to faddism because there is internal and external pressure to improve the public's health and public health systems. "More scholars are studying and writing on the topic, more research is emphasizing a systems view, and ambitious attempts are under way to focus practitioners on improving overall system performance."[13] Systems thinking is being "enthusiastically put" into various fields and organizations from engineering to earth sciences and from organizational management to evaluation. In public health, interest in systems thinking is quite new, but even in these other fields, it is only in its adolescence. Yet, Trochim et al. write, "Despite the growing cognizance of and support for 'systems thinking' in public health, implementation of effective systems approaches remains challenging."[13(p504)]

It is reasonable to expect that the more positive support that exists for systems thinking and the more hope and potential that researchers and scholars attribute to it, the more dialogue, criticism, and skepticism will enjoinder the debate. Yet, as more and more practitioners become aware of systems thinking, more and more will demand accurate and agreed-upon descriptions of what it is and how to implement it. In this regard, whether the field of application is engineering, public health, or some other field, it will be up to the systems thinkers and researchers of systems thinking itself to more adequately define its boundaries, working definitions, methods, and meanings. Therefore, this challenge lies more squarely in the domain of the field of systems thinking. At the same time, the challenges that arise from attempts to implement systems thinking in public health or other fields will provide invaluable feedback to systems thinkers and will help both researchers and practitioners bridge implementation efforts with the theoretical and conceptual work of systems thinking itself.

The current state of systems thinking in public health is a nascent state marked by all the hope, support, and potential associated with a newborn. Yet, existence comes with its bumps and bruises, and one can reasonably predict that with increasing public exposure in the public health arena, systems thinking will need to face tough criticisms. If the systems thinking field, in lockstep with practical fields such as public health and other areas where it is being implemented, can leverage this criticism toward increased clarity of construct and purpose, then it may play an important role in the future.

Methodology in the Literature

This section is a review of the methodologies used in the public health literature. A heuristic is used to identify and categorize 188 publications and to isolate those studies that focus on systems thinking as their object of study. In particular, the objective is to identify empirical studies of systems thinking in public health and to compare and contrast these studies with this study in terms of methodology. At the end of the chapter, the significance of this study is considered.

Boote and Beile[10] propose that a “good” literature review will “consider the research methods used in that literature and consider the strengths and weaknesses of those research methods in relation to the state of the field. In many cases, the body of literature on a topic is limited by the research methods used and advances within the field can be traced back to increased methodological sophistication.”[10(p2)]

In an analysis of the various methods used by researchers in systems thinking and public health, the heuristic in Figure 4.1 assisted in identifying methodological usage.

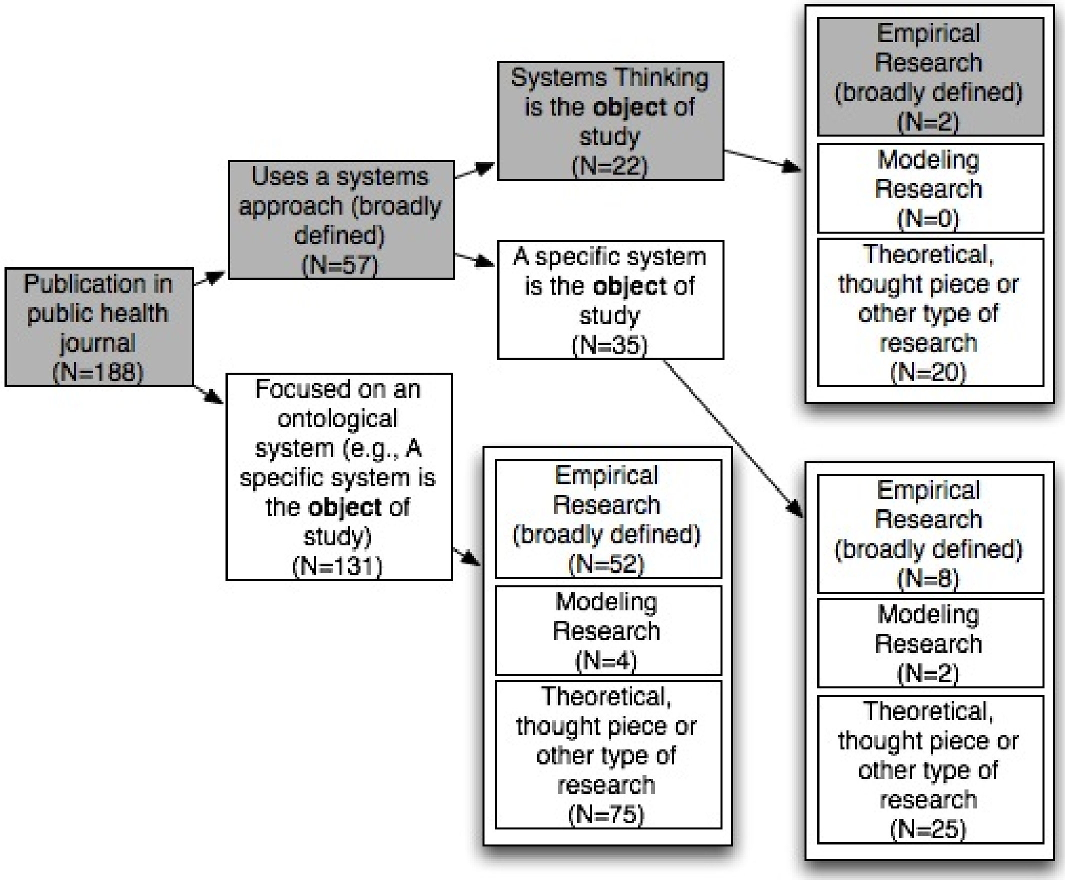


Figure 4.1: Methodology Analysis Heuristic Used for Including/Excluding Publications

The number of publications (N=188) classified using the heuristic in Figure 4.1 is shown for each of the sub-classifications and in summary in Table 4.1. The grey boxes in Figure 4.1 show the publication "path" that is most necessary in the field (public health publications using systems approaches to study systems thinking using empirical methods). The field of public health is extremely broad; therefore, it is likely that this methodological review does not contain every publication having to do tangentially or centrally with systems. The sample of publications (N=188) for this methodological review is not exhaustive and likely could not be. This sample was selected based on key word searches in public health journals of terms such as "systems thinking" and "systems." A complete listing of the publications considered with specific classification, descriptions of methods, sampling, and other bibliographic information can be found in Appendix 4A. This analysis shows that there are many publications (N=131) for which the focus is a specific (ontological) system of some kind. Such systems include management systems, nursing systems, the heart as a dynamic system, syndemic disease systems, networks of practitioners, and the like. There are likely an infinite number of systems that may be relevant to public health, and it is conceivable that each of these systems could be studied. Significantly fewer publications (N=57) take a systems approach (broadly defined). A "systems approach" means that the publication approaches the object phenomenon from one or more of the systems approaches, including a systems science, systems method, or systems theory or idea. Of these publications, only 22 take systems thinking as the object of study. The remaining 35 use a systems approach to study a particular system (e.g., management, leadership, nursing, the heart, syndemic diseases, public health processes). Of the publications that focus on systems thinking as the object of study, there were many more (N=20) theoretical, thoughtful, or other types of publications (e.g., reports, etc.) than there were empirical investigations (N=2).

Table 4.1: Summary for Methodological Classifications

Classification by Method	N
Public Health Focused	188
Uses a Systems Approach	57
Systems Thinking as Object of Study	22
Empirical (broadly defined)	2
Modeling	0
Theoretical/Thought Piece/Other	20
Specific System as Object of Study	35
Empirical (broadly defined)	8
Modeling	2
Theoretical/Thought Piece/Other	25
Ontological Systems Focused	131
Specific System as Object of Study	131
Empirical (broadly defined)	52
Modeling	4
Theoretical/Thought Piece/Other	75

In the context of all of these publications, the two most related to the current work herein are the empirical investigations that focus on systems thinking as the object of study. For the purpose of this analysis, the term "empirical" was defined very broadly to mean "any methodical process" (qualitative or quantitative). This might include interviews, surveys, explorative studies, case studies, quasi-experimental designs, or experimental investigations.

The first empirical investigation into systems thinking in public health is Lammers and Pandita's "Appying Systems Thinking to Public Health Leadership."[175] Although the study was not specifically on systems thinking in public health, it was included in order to use as broad a brush as possible. In actuality, this study investigates leadership and decision making in public health and uses systems thinking as a framework for analysis. Nevertheless, Lammers and Pandita used a survey and follow-up interviews with "all of the health officers and all department executives in California"[175(p40)] to identify leadership challenges. They classified "decisions faced by respondents into eight [sic] areas"[175(p40)]: budget, programming, managed care issues, disease control, and three types of staffing challenges (environmental, illegal aliens, and undocumented care). Two of their findings are particularly relevant. First, leaders expressed that one challenge was that there were time lags before decisions took effect, and the other was that "problems resulted from solutions."[175(p40)] Lammers and Pandita's sample and method are well-suited to the task, but the object of the study was not systems thinking per se, but leadership challenges. In addition, the focus was not specifically leadership challenges related to systems thinking. Instead, it appears that systems thinking was used as a lens through which the participants' responses were analyzed. Nevertheless, the study does contribute to the body of research on challenges of leadership in public health that seem to indicate the need for systems thinking.

The second empirical study that took systems thinking as the object of its study is Huz et al.'s[158] "A framework for evaluating systems thinking interventions: An experiential approach to mental health system change." It should be noted that this study, while specifically focusing on systems thinking as the object of investigation, does so with the implicit assumption that systems thinking and system dynamics are synonymous, or at least are more similar than systems thinking and, for example, complex systems, GST, or other systems theories or ideas. This does not mean that the study is not a meaningful contribution, only that the systems thinking construct being used in the study may be limited in its scope and therefore may lack construct validity in terms of generalization to systems thinking, more broadly defined. Huz et al. state:

> This research calls for a similar systems thinking intervention to be repeated in four counties with four control counties also selected and observed via pre- and post-intervention measures. The overall context of the project focuses on integration of mental health and vocational rehabilitation services. The experiment is designed to evaluate measurable outcomes, including shifts in goal structures and change strategies of the management team, shifts in relative alignment of the management team as a whole, perceived success of the

> intervention, and changes in systems and procedures necessary to improve client services. This article presents a framework for evaluating systems thinking interventions as well as preliminary findings from the pilot test.[158(p149)]

And earlier Huz et al. state:

> Increasingly, the field of system dynamics is moving beyond conceptualizing, formulating, and analyzing formal simulation models as a way to affect the performance of groups and individuals. A variety of systems thinking interventions are being combined with simulation in many system dynamics projects. These include simulation-based games, the construction of "learning environments," qualitative analysis of systems using archetypes of system structure and behavior, and the direct involvement of management teams in model construction and system conceptualization in group model building sessions.
>
> This relative explosion of new approaches to transferring system insights to individuals and groups of managers is closely related to a number of other system thinking approaches many of which pre-date their development and use with formal system dynamics simulation models (Richardson, Wolstenholme and Morecroft, 1994). These new approaches to systems thinking have generated much interest in the clients of system dynamics studies and have been the foundation upon which a number of new consulting firms have based their practices. However, much of this apparent success has not yet been systematically evaluated.[158(p149)]

These statements are methodologically relevant for two reasons. First, it is clear that the pilot evaluation project has been well staged. With the assumption that the field of system dynamics is "moving beyond conceptualizing, formulating, and analyzing" the various ideas in the field, it is now possible to do more formal evaluation research on learning outcomes for "systems thinking" using "control groups," "pre- and post- intervention measures" and experimental methods. The ability to move to these more refined types of methods, however, is predicated on the construct validity of the systems thinking construct used in the study. Because Huz et al. use a very narrow construct for systems thinking that does not take into account many of the important concepts included in knowledge-about-systems, it is possible to use such methods. It is ironic that adherence to the methodological progression that Huz et al. imply (e.g., the medical style model that progresses through explorative, correlational, experimental, and implementational stages) is what is most necessary in investigating the systems thinking construct more broadly defined.

Both of these studies were explorative. Both use appropriate methods and sampling procedures for the particular study. In addition, both studies make meaningful empirical contributions to the field of public health and to systems thinking. Yet both studies are also limited in their contribution for different reasons. Lammers and Pandita's was not specifically focused on systems thinking as the object of study but was "retro-fitted" with systems thinking during the analysis, and the study by Huz et al. is questionable because the systems thinking construct they use in their study is so narrowly defined.

Because systems thinking in public health is a new endeavor, the number of "thought pieces" and editorials is expected to be high. It is appropriate for scholars to enter into dialogue regarding the issues presented as consideration is given to the challenges of implementing systems thinking in public health settings. Theoretical pieces are less appropriate without some empirical grounding. Modeling, sometimes called the "third research methodology," is also appropriate for simulating public health systems; however, it must be supported by empirical research. This is not to say that there is not a great deal of systems-oriented empirical research occurring in public health. Many excellent empirical studies have tackled tough problems associated with systems phenomena in public health. However, these research studies are focused on the various systems they study, not on systems thinking as a phenomenon in and of itself.

Two things are evident from this analysis. First, additional empirical research is needed in order to understand the challenges of implementing systems thinking in public health. Second, alternative methodological innovation must take place in order to contribute to the fields of systems thinking and to public health.

One methodological contribution is to use systems-based methods to study systems-based public health initiatives that are attempting to implement systems thinking—in a "mise en abime" approach. *Mise en abime* is a French term that literally means "placing into infinity" or "placing into an abyss." The term refers to the formal technique in Western art replicating an image within itself, recurring to infinity. A study that uses systems methods (such as structured conceptualization)[176] to study systems initiatives that are attempting to implement systems thinking will be a worthwhile methodological contribution to public health because it would demonstrate systems approaches on multiple levels.

Whenever one wants to identify what a particular group thinks about a particular topic, the structured conceptualization method—a mixed research method that subjects brainstormed statements to sorting and rating, and subsequently subjects the resulting data to multivariate statistical analysis—is a useful method. Because the field of systems thinking in public health is new, and because so much of the literature is conceptual or editorial in nature, structured conceptualization methodology is well-suited to "planting an empirical stake in the ground."

Significance of the Research Problem

As Green[141] points out, the endeavor to use systems thinking in public health is a research-to-practice endeavor. Therefore, it is critical to research and analyze the challenges to implementing systems thinking in public health and to relate these findings back to the conceptual field of systems thinking. The significance of this research is that it does both. Boote and Beile[10] differentiate between scholarship and research, between a scholar and a researcher, and between the literature review and the research itself. A good literature review, they suggest, is central to good research.

They also suggest that a good literature review explains both the practical and scholarly significance of the research problem.

The literature review presented in Chapters 2–4, and the research described in the following chapter, conform to all of these requirements. That is, the review is a significant contribution to practice, scholarly work, and research in both systems thinking and in systems thinking in public health.

A critical review of the literature leads to the conclusion that many definitional ambiguities and misconceptions exist in systems thinking and that these definitional problems will lead to challenges when practitioners attempt to implement systems thinking in public health. This problem is as much the concern of researchers and practitioners as it is of the separate fields of systems thinking and public health. In addition, as a conceptual ability, systems thinking benefits from the development of new systems methods and the new application of those methods in a systems context. The use of structured conceptualization, a systems methodology, to study the challenges of implementing systems thinking in a public health context is also a contribution to existing systems methodology. The "mise en abime" approach (e.g., research using a systems method to study systems initiatives implementing systems thinking) is also a unique and innovative contribution to the fields of systems thinking, public health, and systems methodology. If hypothesis of this study is correct, that definitional ambiguities and misconceptions in systems thinking will lead to challenges as practitioners attempt to implement systems thinking in public health, then the four new perspectives offered above are also a significant contribution to the fields of systems thinking and education. Once conceptual clarity in the construct of systems thinking develops, then educators will be better equipped to teach these powerful "habits of mind" to current and future generations. The significance of this study, of both the literature review and the research, is that it will lead the field toward a more robust conceptual theory of systems thinking.

Chapter Five

Methods

The purpose of this research is to ascertain the degree to which definitional ambiguities and misconceptions in systems thinking lead to challenges as practitioners attempt to implement systems thinking in public health. It is clear from the literature on systems thinking in general, and in public health in particular, that construct ambiguities exist. It is also clear that the systems thinking construct continues to evolve as understanding deepens over time. Yet there is no research that helps us to discern the current state of the systems thinking construct within the context of implementation challenges. This research provides a "snapshot in time" of both the discernment and ambiguities of the systems thinking construct as practitioners attempt to implement it in a public health setting.

Using a mixed method called *structured conceptualization*, or *concept mapping*, this study was conducted to provide a better understanding of the practical challenges to the implementation of systems thinking in public health. This study was conducted between December 2004 and January 2005. The purpose of the project was to develop a conceptual framework of the challenges that public health researchers and practitioners face in implementing systems thinking. In addition, this project was undertaken to help to empirically frame an invited paper for the *American Journal of Public Health* volume on systems thinking. Of particular interest is the unique conceptual approach used in this study—that is, a *mise en abime* approach—in which a systems method (structured conceptualization) was used to study the challenges of implementing systems thinking within systems-based initiatives. A structured conceptualization approach enables groups to express their ideas on a particular topic and generate a conceptual map of these ideas. The "core group" for this study consisted of two public health experts who co-led the two leading systems thinking efforts in public health (ISIS and Syndemics), a research methodologist familiar with public health and systems thinking, and a graduate student in education with expertise in systems thinking.

This chapter describes the rationality of the structured conceptualization method chosen for this research over other methods. In addition, this chapter describes in detail the first four steps in the structured conceptualization method: preparation, generation, structuring and representation.

Best Fit: A Systems Methodology.

Structured conceptualization is one hybrid mixed-method approach to social research inquiries. Content analysis, surveys, narrative inquiry, or interviewing, for example, may have been appropriate methods to use in examining the implementation challenges of systems thinking. However, structured conceptualization is ideally suited as a method whenever one wants to better understand how a particular group thinks about a particular topic. Therefore, this method is well-suited to analyzing how an actual group of public health practitioners conceptualizes systems thinking and some of the various challenges associated with its implementation. All social research is predicated on some conceptualization of a phenomenon. Often, this conceptualization relies solely on extant theory that includes the personal intuitions and experiences of the researcher but is not tested in an empirical sense. Structured conceptualization offers a method that addresses this issue and is especially useful when conceptualizations of a topic are ill-defined or defined in many different ways. As was addressed in previous chapters, systems thinking is a broad concept characterized by a high degree of complexity and by fragmented or diverse conceptualizations.

Structured conceptualization, for both theoretical and methodological reasons, provides an opportune methodology for understanding how a group of practitioners conceptualizes the construct of systems thinking as well as its sundry implementation challenges. It is also a useful methodology for practical reasons. Because this study was conceived from both theoretical and practical perspectives, it was necessary and important to ensure that the results of the study would be as useful to researchers generating theory as they would be to practitioners. The lack of clarity about systems thinking and the lack of knowledge about the challenges to its implementation are both theoretical and practical issues: theoretical, because the construct of systems thinking, without the aid of a systematic framework for generating it, lacks construct, internal, and external validity; practical, because the implementation of the systems thinking construct is characteristically misunderstood, and this lack of knowledge presumably leads to implementation failures or acts as a barrier to those who might otherwise envision systems thinking as part of a larger change effort.

A structured conceptualization methodology is well-suited to situations in which research and practice need to be linked. First, because structured conceptualization is a hybrid social research method, comprised of both qualitative and quantitative methods and techniques (such as brainstorming, Likert-style rating scales, cluster analysis, and multidimensional scaling), it provides the empirical basis for scientific and theoretical research. In particular, structured conceptualization is an excellent method for getting purchase on a particularly complex social issue containing multiple perspectives. At the same time, structured conceptualization is participatory—involving the participants in aspects of the research process—and the knowledge generated from structured conceptualization, partly because of its output in the form of visual maps, pattern matches, and "go zones," is both useful and accessible to practitioners. In an arena in which the construct validity of systems thinking and its implementation challenges are vague or unsystematic, where there was a desire for both theoretical and practical utility, and where the researchers had the opportunity to access a large group of practitioners using participatory methods, structured conceptualization proved to offer the best methodological fit.

Structured conceptualization consists of four initial phases that combine mixed methods into a hybrid methodology: preparation, generation, structuring, and representation. Further phases will be described later in Chapter Six on Results.

Preparation

Developing the focus prompt

Developing the focus prompt is an important first step in the structured conceptualization process. A focus prompt is a primer for the participants in the study and must be carefully constructed in order to clearly direct the generation of statements in the brainstorming process. The focus prompt for this study was:

> One specific practical challenge that needs to be addressed to encourage and support effective systems thinking and modeling in public health work is...

The focus prompt is contextualized by various clarifying definitions and descriptions. First, the participants received an email explaining the project (See Appendix 5A); second, each key term in the focus prompt (i.e., “specific practical challenge” or “public health work”) was described in greater depth on the brainstorming Web page (See Appendix 5B).

Selecting the Sample

Because of the theoretical and practical nature of the focus prompt, it was necessary that the sample for the study be drawn from both applied and research arenas in public health. Because the focus prompt was based on applications of systems thinking, it was determined that the sample should include systems thinkers involved in implementation efforts. The sample consisted of public health professionals, researchers, and applied systems thinkers. In addition to public health professionals and applied systems thinkers, the sample was designed to include participants from multiple levels in the large public health system (e.g., policy makers, administrators, researchers, field staff, medical personnel, etc.) Thus, the sample was selected based on the following criteria: (1) involvement in applied systems thinking, (2) involvement in the public health system, (3) availability or accessibility (e.g., initiative email lists).

Two email distribution lists (N=374) were available, as well as correspondence with initiative leaders from the National Institutes of Health and Tobacco Control, which included email addresses for public health practitioners and policy makers from two initiatives: The Initiative for the Study and Implementation of Systems (ISIS) and the Syndemics Prevention Network (SPN). Participation rates for each of the phases are shown in Table 5.1:

Table 5.1: Descriptive Statistics of Participation Rates

Response Rates	Total Emails	Visitors Phase 1	Logins Phase 2	Sort Completed	Rate Completed
Total Emails*	**359**				
Visitors Phase 1	37.05%	**133**			
Logins Phase 2	22.01%	59.40%	**79**		
Sort Completed	15.60%	42.11%	70.89%	**56**	
Rate Completed	15.04%	40.60%	68.35%	96.43%	**54**

** Total emails: 374 minus 15 undeliverable emails*

Table 5.1 shows that 374 total emails were sent and lists the subsequent response rates for each phase of the project (the phases will be discussed in greater depth later). Of these, 15 undeliverable emails were not included in the descriptive statistics of participation (There were 359 deliverable emails sent). These emails generated 133 visitors to the brainstorming Web site (or 37.05% of deliverable emails). Log-in during the brainstorming phase (Phase 1) was not required, in order to increase the possibility of participation and decrease the number of people who would not participate if they were required to log in. The Concept Systems®[177] software[2] (used in this study) did not track whether visitors contributed, only whether they visited the brainstorming Web page. As a result, it is not possible to tell if the participants who brainstormed are different from those who logged in during the sort and rate phase (Phase 2). Assuming that the logins for Phase 2 (sorting/rating) were a subsample of the visitors for Phase 1, of the 133 visitors, 59.4%, or 79 participants, logged into the Phase 2 Web page. These 79 participants represent 22.01% of the deliverable emails. Of these 79 participants, 70.89%, or 56 participants, completed the sorting. These 79 participants represent 42.11% of the Phase 2 logins and 15.60% of the total deliverable emails. Finally, 54 participants completed the ratings, representing 96.43% of participants who completed sorts, 68.35% of participants who logged in for Phase 2, 40.6% of visitors to the brainstorm Web page, and 15.04% of the deliverable emails.

Generation

Brainstorming Phase

After the preparation phase, in which the focus prompt is developed in conjunction with sample selection, the next step in the structured conceptualization process is brainstorming. Structured conceptualization allows for synchronous or asynchronous brainstorming as well as online or in-group brainstorming. Because the

[2] The Concept Systems® software used in this research was provided by Concept Systems, Inc., through an exclusive educational license to Cornell University. For information about the software see the website (http://www.conceptsystems.com) or contact Concept Systems, Inc., staff directly at: 401 East State Street, Suite 402, Ithaca, NY 14850; Tel: 607.272.1206

study sample was drawn from throughout the United States, it would have been impractical to use in-group, synchronous brainstorming. In addition, because of busy schedules and time constraints of the sample, synchronous brainstorming of any kind, even online, would have been impractical. It was decided that online, asynchronous participation was the best option because the online version of the structured conceptualization software is more user friendly, readily accessible at any time during the phases to the participants, and less logistically intensive than paper, group meeting, or fax-based options.

The brainstorming phase began with an email invitation to participate (see Appendix 5A). Emails were sent, using a desktop email client, to each of the email addresses on the distribution lists, asking recipients to participate in the study and providing them with a link to a Web page (See Appendix 5B). People who chose to participate were self-selected by involving themselves in the brainstorming phase. Once participants reached the Web page they were given text directions and context for the study and introduced to the focus prompt. Each of the key phrases in the focus prompt was described in greater depth for priming purposes. Participants were instructed to submit single statements that completed the focus prompt, and they were told that they could submit, one at a time, as many statements as they desired. As soon as a statement was added and the participant pressed the submit button, his or her entry was shown among the other entries on the page, and the participant was given the option to add another entry or to quit. In this way, participants could submit multiple entries and, as in group brainstorming, they were aware of the responses of others. This means that each response may have had generative affects on subsequent responses. Although it is not possible to know how many of the original emails led to participation, some of the server statistics for the brainstorming phase are shown in Table 5.1.

During the two-week brainstorming phase, 315 original statements were generated. After the specified period, the brainstorming phase was closed.

Statement Synthesis/Reduction

Once the original 315 statements were received, the next step in the process was to synthesize and reduce these statements into a representative set of statements for sorting and rating. This step is also sometimes referred to as the "reduction of statements." The result of this process is the transformation of "original statements" into "synthetic statements." The purpose of this phase was fourfold: (1) to reduce the entities to a reasonable number (e.g., <100) that participants could feasibly sort and rate (primarily to increase the probability of participation), (2) to check entities for clarity and conciseness such that each statement could be understood by the sample, (3) to check entities for consistent format such that each statement grammatically completed the focus prompt, and (4) to combine redundant or highly similar statements and/or to decouple compound statements.

The process of reduction/synthesis is essentially a process of coding and categorization on the part of the researcher. However, all of the researcher coding and categorization is intended only to reduce the large quantity of statements into a clear, concise, grammatically correct and manageable set of synthesized statements. Once this is accomplished, the researcher randomizes the final statement list to ensure that his or her specific coding schemes are not biasing statement ordering or participant sorting.

There are numerous coding schemes that researchers can use. In previous concept mapping studies, reduction traditionally used an ad hoc heuristic devised by the researcher with or without the use of programs such as "Key Words In Context" (KWIC). However, there are several standard requirements that must be a part of any reduction/synthesis process. First, the researcher must keep an audit trail from the original entity through iterations and reductions to the final synthetic statement; in other words, each final statement should be linked through its parent states to its origin statement. Second, it is important to address the possibility that statements could be lost in the process by having multiple researchers ensure that reductions and syntheses are appropriate. Finally, it is critical that the final list of synthetic statements is randomized so that they are not ordered in a manner that would influence the sorting and rating by participants.

In this research project, the researcher used an Excel spreadsheet as a tracking mechanism and to create an audit trail for all reduction/synthesis activities. First, the master list of 315 statements was read for content clarity to ensure that each statement could be understood by the researcher. Software and/or techniques such as "Key Words In Context" (KWIC) could be used in this stage but were not because the researcher decided that the results of KWIC did not adequately represent the meaning of the content. Therefore, a simple coding scheme was used: a descriptive word or phrase was placed into a column to the right of each statement, followed by a secondary word or phrase in the next column. Then, statements were sorted by similar words or phrases and subsequently moved to categorical tabs in the spreadsheet. This process allowed the researcher to "chunk" the large set of entities into smaller but related sets that were more manageable (See Figure 5.1).

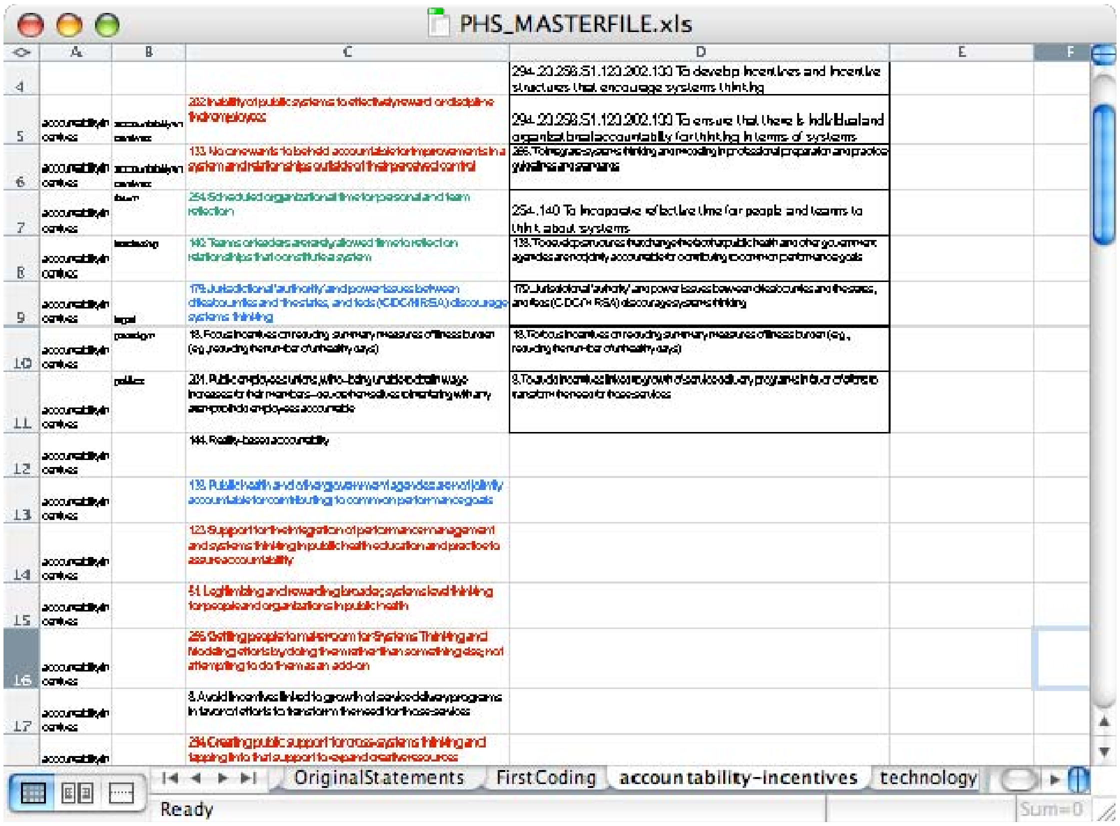


Figure 5.1: Researcher Coding Heuristic Using Excel Spreadsheet and Tabs

Thirteen researcher subcategories were created in order to chunk the data and find similarities in the entities that could be reduced for synthesis to fewer statements. Within each of these subcategory tabs, the researcher used color and grouping to further "chunk" the entities in order to find similarities. In addition, care was taken to keep a "phylogeny" of the changes to entities using a simple numbering system. All records for the project were kept in a single Excel file for ease of reference and retrieval and for archival reasons. The phylogeny of entities to statements could be tracked using this Excel file by moving from left to right or backward from right to left, both within tabs and across tabs. In each of the thirteen subcategories, entities were read and compared until the researcher made the decision that saturation of synthesis had been reached.

In the next step, a new tab was created for the initial list of synthetic statements (n=126). A new comparative method was used to engage in further synthesis using multiple independent reviewers, for two reasons: (1) the primary researcher had reached a point of saturation in the statement reduction, and (2a) it is useful to have multiple reviewers spot-check the validity of reduction-decisions as well as (2b) to determine whether each of the original entities is represented in the final statement synthesis, and (2c) to assist the primary researcher in reducing the statements to the desired number (n=~<100). The comparative method used was to set up columns: Column A with phylogenic numbers denoting the original entities that influenced the creation of the synthetic statements; Column B with the synthetic statements; Column C, representing the transformation from pre- to post- reviewer statements; and Column D, consisting of the statements after the review. Reviewers were instructed to review each entity and statement for: (1) minor editing, (2) grammatical correspondence to the focus prompt, (3) repetition, (4) similarity, and (5) validity of reduction. The categories used by the primary researcher were no longer associated with the statements and were not available to the reviewers, nor were they used in or relevant to the remainder of the study or the analysis. Reviewer #1 reduced the 126 statements to 95. Reviewer #2 made minor changes and increased the number of statements from 95 to 98. Reviewer #3 made minor changes and some edits and increased the number of statements from 98 to 100.

At this point, the statement synthesis was finalized and statements were moved to a new tab to be randomized using a random number generator in Excel (=RANDBETWEEN(1,100). This was an especially important step in the preparation of the statements as it ensured that any residual effects of the primary researcher’s heuristic categorization of the entities did not lead to similar statements being close to each other and therefore sorted together by participants in the sort and rate phase of the study. At this point, each synthetic statement received a unique number identifier (ID) which was used for the remainder of the study and in the maps and analysis. A list of the original statements and their phylogenic paths can be found in Appendix 5E.

Structuring

Developing Demographic Variables for Study

At this point, the second phase of the project begins. Demographic variables of interest to the researcher were administered in the sort and rate phase of the research. For this study, three demographic variables were chosen (see Table 5.2).

Table 5.2: Respondent Questions Statistics

Respondent Variable	**Categories**	**Frequency**	**%**
Formal Training	Academic degree	6	10.34%
	None	16	27.59%
	Occasional Course/workshops	36	62.07%
	Totals	**58**	**100%**
Practical Experience	1 or more project(s)	46	79.31%
	Never	12	20.69%
	Totals	**58**	**100%**
Professional Role	Business	5	8.62%
	Educational (school, college, university)	20	34.48%
	Not for Profit or NGO	11	18.97%
	Other	22	37.93%
	Totals	**58**	**100%**

The first variable was chosen to reflect the level of formal training respondents had in systems thinking or modeling. Formal training may influence the sophistication with which respondents understand systems thinking and modeling and therefore alter how they sort or rate the statements. For this variable, 6 participants, or 10.34%, held academic degrees in systems thinking or a related field; 16 participants, or 27.59%, had no formal training; and 36 participants, or 62.07%, had taken occasional courses or workshops. The second variable, "Practical Experience," was chosen for similar reasons but based on practical or applied experience in systems thinking and modeling rather than formal or academic training. For this variable, 46 participants, or 79.31%, answered "1 or more project(s)" and 12 participants, or 20.69%, answered "never." Finally, "Professional Role," was chosen in order to determine how different respondents sorted and rated statements based on the type of organization in which they worked. For this variable, 5 participants, or 8.62%, answered "business"; 20 participants, or 34.48%, answered "educational"; 11 participants, or 18.97%, answered "not for profit"; and 22 participants, or 37.93%, answered "other." The "core group"—the researcher, two professionals from CDC and NCI, and one research methodologist from Cornell University—reviewed the demographic variables before finalizing them in Phase 2.

Developing the Importance Rating

The importance rating for the Rating task centered around the core idea of the focus prompt—a challenge that must be addressed to encourage and support systems thinking and modeling in public health. The instructions for the importance rating were:

> Rate each of the idea statements according to how important it is (compared to the other statements) in terms of being a challenge that must be addressed to encourage and support systems thinking and modeling in public health.
>
> 1 = relatively unimportant compared to the rest
>
> 2 = somewhat important compared to the rest
>
> 3 = moderately important compared to the rest
>
> 4 = very important compared to the rest

5 = extremely important compared to the rest

The "core group" reviewed the instructions for the importance ratings before finalizing them in Phase 2.

Developing Web Site and Fax-back Option

Like the brainstorming phase, the sort and rate phase took place asynchronously over the Internet. However, in order to ensure as much participation as possible, a fax-back option was also made available. The fax-back option and the Web-based option, other than the process used to complete the task, utilized the same research materials, statements, sorting and rating methods, demographic variables and importance rating. For the Phase 2 email, see Appendix 5C. For snapshots of the various Web pages that participants used, see Appendix 5D.

A mail-merge client software was used to send user IDs and passwords to the two email distribution lists used in Phase 1. The use of a User ID and password ensures that users can complete the 45-minute to 1-hour task over several sessions if desired and is therefore important for increasing response rates as well as addressing privacy issues. In addition, during the three weeks that the sort and rate phase was "open," two reminder emails were sent to those individuals who had not yet responded.

Representation

Data Entry into Concept Systems Software

After the sort and rate phase was completed, data were downloaded from the Web for analysis. Each participant's responses were checked for completeness. Incomplete records, where sorting and/or rating were not completed, were not used. In addition, per the instructions to participants, the sorting process did not allow miscellaneous or "other" sort piles; therefore, the researcher identified participants who created such piles. When such piles were identified, the researcher executed a script in the software to separate each statement in the pile into piles of one. This enabled the analysis to handle the data appropriately. At this point in the process, the researcher prepared the data for analysis and the generation of concept maps.

Generate Concept Maps

A concept map, the basic output of the structured conceptualization method and software, was generated using three multivariate statistical methods: multidimensional scaling (MDS), a hierarchical cluster analysis, and a computation of average ratings for each statement and cluster of statements. Sort data for each participant was entered into an N x N binary similarity matrix (S_{NxN}), where N is equal to the number of statements (N=100). If the participant, for example, sorts statement numbers 42 and 71 into the same category, a 1 is placed at the intersect of the 42nd column and 71st row (as well as the 42nd row and the 71st column because it is a symmetric matrix). If the participant, *did not* sort statement numbers 42 and 71 into the same category, a 0 is placed at the intersect of the 42nd column and 71st row[178] (as well as the 42nd row and the 71st column). In this study, 56 participants completed the sorting activity. Therefore, 56 different 100 X 100 binary similarity matrices were generated. Because these "individual participant sorts" can be thought of as stacked like sheets of paper, the matrices become a 3-dimensional cube called a "total similarity matrix" (T_{NxNxP} or $T_{100x100x56}$). Then, the sum of each column of cells was derived by "drilling down" through each cell (for example, the cell that represents whether people grouped statement numbers 42 and 71 together). The more 1's in the cells representing statement pairings, the higher the final sum will be for the statement pairing. The higher this final sum, the more closely related the statements were (because it means more people sorted them together). This binary symmetric similarity matrix was then entered into the MDS algorithm[179] with a two-dimensional solution (x,y). Kruskal and Wish[179] explain:

> Since it is generally easier to work with two-dimensional configurations than with those involving more dimensions, ease of use considerations are also important for decisions about dimensionality. For example, when an MDS configuration is desired primarily as the foundation on which to display clustering results, then a two-dimensional configuration is far more useful than one involving three or more dimensions.[179(p2)]

Figure 5.2 shows the MDS algorithm. The MDS analysis produces a two-dimensional (X_{Nx2}) result that was the input for hierarchical cluster analysis using Ward's algorithm[180] for grouping the statements into clusters. Trochim[178] writes, "Using the MDS configuration as input to the cluster analysis in effect forces the cluster analysis to partition the MDS configuration into non-overlapping clusters in two-dimensional space."[178]

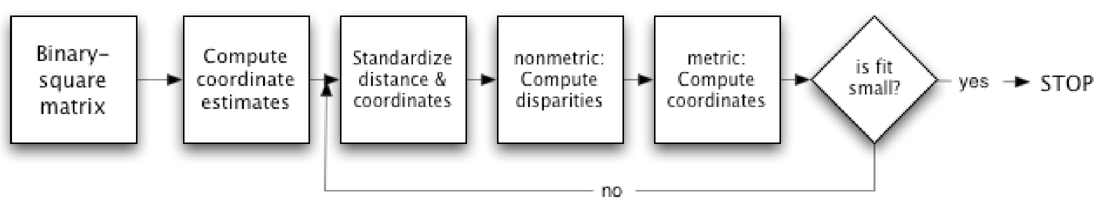


Figure 5.2: Multidimensional Scaling Algorithm[181(p104)]

The MDS analysis produces a stress value for each study. The stress value indicates goodness-of-fit. If the stress value is low, then the fit is better. Trochim[178] reports that average stress value for 38 projects was 0.285, ranging from 0.155 to 0.352. The stress value for this study was .301 over 27 iterations.

Once the MDS and cluster analysis was completed, the next step in the structured conceptualization method begins. The next step, *interpretation*, involved using the generated maps along with a subsample of participants to give appropriate names to certain points or regions in the map. This interpretation process will be discussed in the next chapter.

Chapter Six

Results

This chapter contains the interpretation of the research described in Chapter Five. Specifically, the statements generated by participants, the sorting and rating activities, and the generation of concept maps are discussed. In order to assess the reliability of the concept maps, a split half test is used. A multiple comparison test is used to determine the statistical significance of the differences between cluster ratings. Throughout the chapter and at the end, several interpretations of the data are proposed.

Summary of Statements, Ratings, and Generation of Maps

The results for the structured conceptualization are “layered,” in that each output can be combined with another output. For example, a point map can be combined with a rating map to produce a point-rating map, and so on. In the next section, one layer will be added at a time to expand on the data.

The first source of data is the reduced set of brainstormed statements that are rated by the participants (see Appendix 6A, which lists each statement number, statement, its average rating (on a scale of 1 to 5) in descending order and its bridging value). The mean rating across statements was 3.34 (SD=0.38). Bridging values refer to the MDS analysis and tell to what degree one statement (point) is related to another statement. Low bridging values are associated with “tight” clusters, and statements with low values can be thought of as “anchors” that participants recognized as core themes while sorting. In contrast, high bridging values are associated with “large or dispersed clusters,” and a statement with a high bridging value can be thought of as a “bridge” between clusters. The range for bridging values is 0 to 1.

A number of visual results can be produced using the Concept Systems® analytical package. MDS analysis using only the reduced statements and the sorting data produces a “point map” (see Figure 6.1). On a point map, each statement is represented by a numbered point. The distance between statements indicates the degree to which the statements are related. If the statements are closer together, more participants sorted them together. Figure 6.1 shows the 100 statements on the MDS point map. Note that, for example, point #20 on the right side of the map was sorted as being very different from (far away from) point #4 on the left-hand edge of the map, whereas point #4 and point #1 are similar because more people sorted them together. Notice that even before cluster analysis, one can see some clustering of the points.

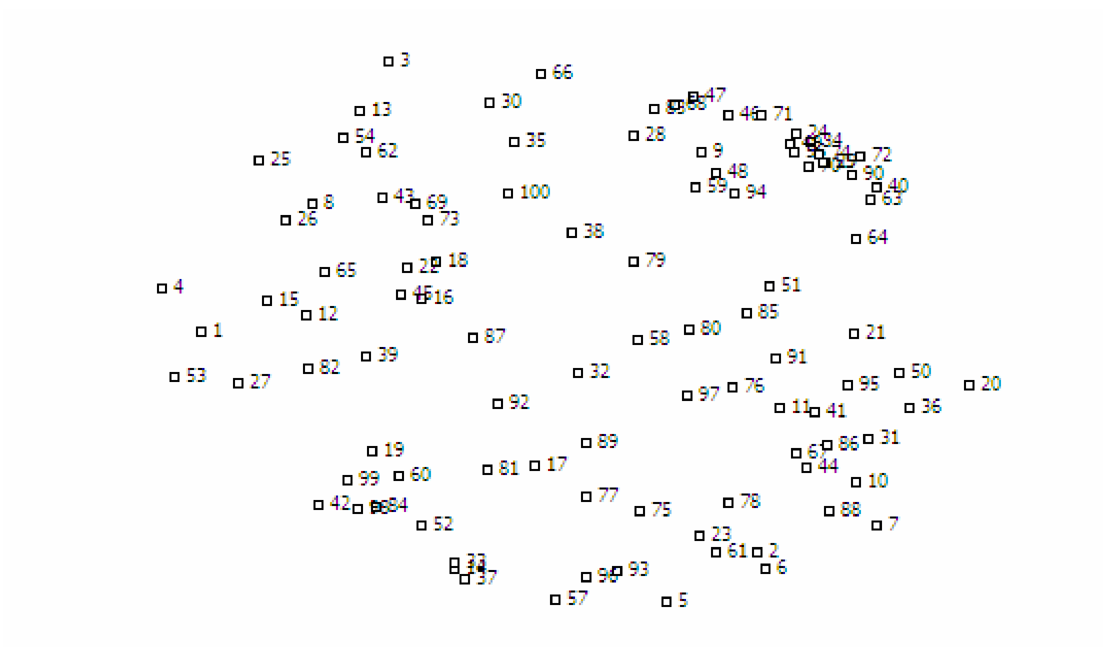


Figure 6.1: Point Map

Next, a “point rating map” is generated from the reduced statements, MDS analysis on the sorting, and the importance rating (see Figure 6.2). The point rating map is the identical MDS configuration to the point map in Figure 6.1, but here ratings for each statement have been added as a third dimension. The higher the stack of squares, the higher the average rating for the statement. Notice that the tight cluster in the upper right contains statements that were rated highly, a slightly less-tight cluster in the lower-left quadrant is also made up of highly rated statements, and the more loosely bound sets of statements in the upper-left and lower-left quadrants are a mix of high and low ratings.

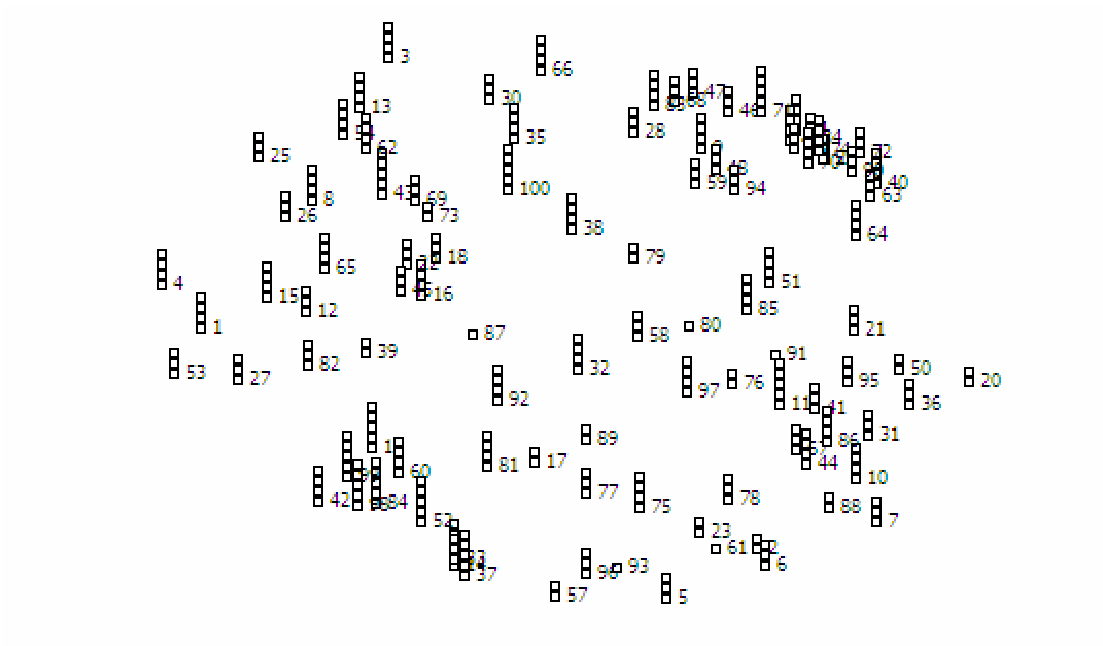


Figure 6.2: Point Rating Map

A “point bridging map” (see Figure 6.3) can also be generated from the same data and analysis. Bridging values for each statement are shown in Figure 6.3. By comparing the point rating map in Figure 6.2 with the point bridging map in Figure 6.3 one can see, for example, a tight cluster with high ratings and low bridging values for statements in the upper-right quadrant. This means that the participants rated these statements high and that there was little uncertainty about sorting these statements together. This cluster, in particular, contains statements that have to do with learning more about systems thinking. A similar cluster (high ratings and low bridging) in the lower-left quadrant of these maps contains statements related to cross-category funding. In contrast, the loose cluster of highly rated statements in the upper-left quadrant have high bridging values, which is evident by the elevation of the stack and the distance between points.

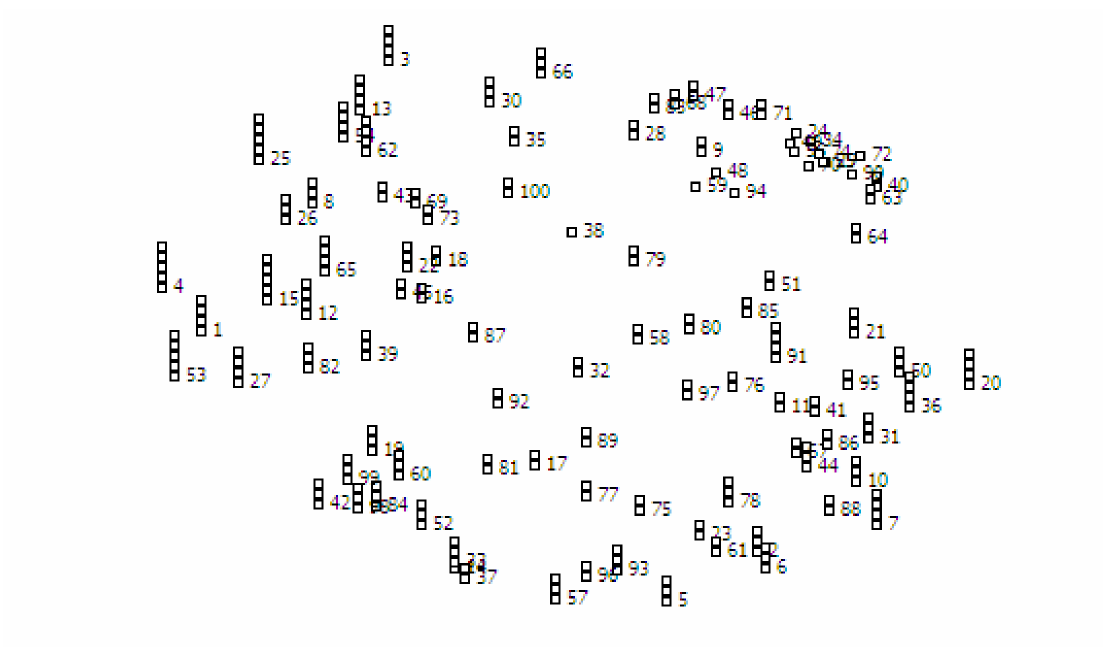


Figure 6.3: Point Bridging Map

The sorting activity allows categorization into clusters based on the multidimensional scaling analysis (MDS) and using the hierarchical cluster analysis. The clustering analysis uses a quantitative clustering algorithm (Ward's algorithm) and qualitative analysis by the researcher. A worksheet detailing the method for choosing the cluster solution, entitled "20-1 Cluster Solution Worksheet"[182] (see Appendix 6B), was used to determine the optimal cluster solution. Using two interpreters for inter-interpreter validation, an 8-cluster solution was selected. After the cluster solution is selected the data are organized into the selected solution, generating the 8-cluster solution map shown in Figure 6.4.

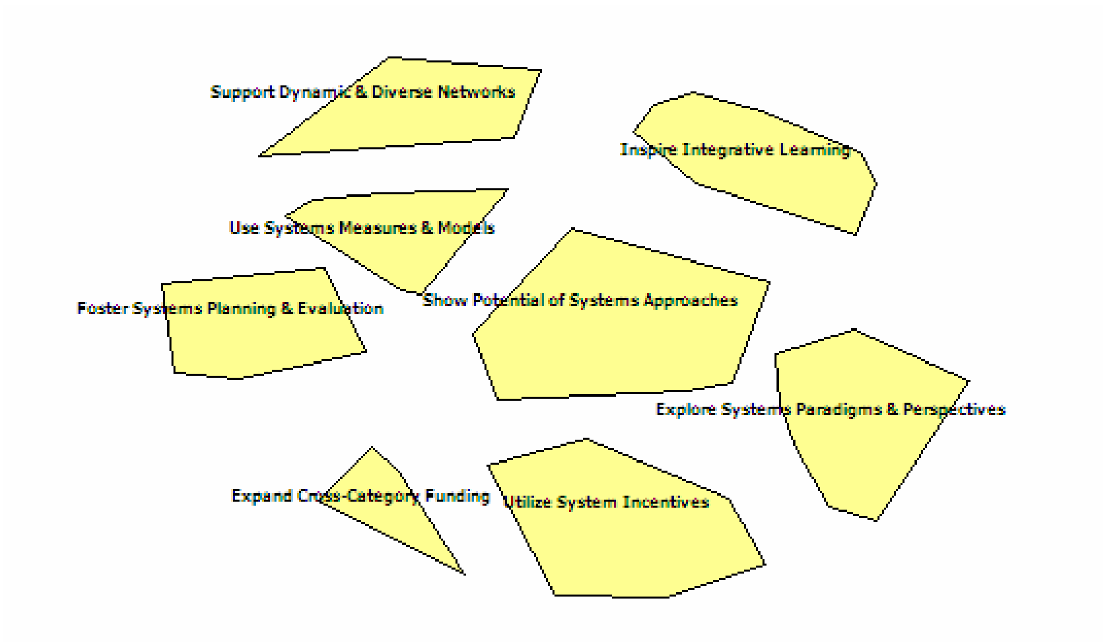


Figure 6.4: Cluster Map

The cluster names were selected by the "core group" during a telephone conference call. A standard methodological process was used in which a PowerPoint presentation was made with each cluster shape and the statements for each cluster. Each participant was asked to name the cluster according to the statements within it. Each participant's answers were discussed, and a synthetic name for each cluster was arrived at by consensus. The names that resulted from this process are shown in Figure 6.4 and in Table 6.1.

Table 6.1: Cluster Names

Expand Cross-Category Funding
Support Dynamic & Diverse Networks
Use Systems Measures & Models
Inspire Integrative Learning
Foster Systems Planning & Evaluation
Show Potential of Systems Approaches
Explore Systems Paradigms & Perspectives
Utilize System Incentives

From the MDS, cluster analysis, and ratings, a "cluster rating map" was generated (see Figure 6.5).

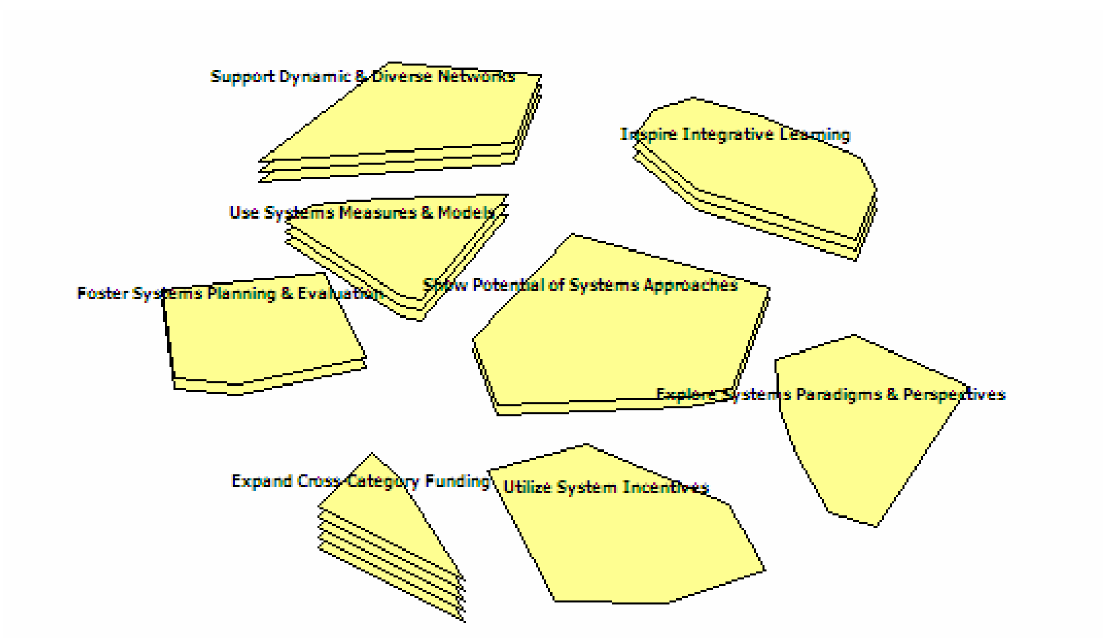


Figure 6.5: Cluster Ratings Map

Table 6.2 shows the summary statistics for each cluster, including the number of statements in the cluster, standard deviation, minimum rating, maximum rating, variance, median rating, and average rating for each cluster.

Table 6.2: Cluster Rating Summary Statistics

Cluster Name	Statement Count	Std. Dev.	Min.	Max.	Variance	Median	Avg.
Expand Cross-Category Funding	10	0.30	3.11	4.13	0.09	4.00	3.86
Support Dynamic & Diverse Networks	8	.20	3.09	3.74	0.04	3.48	3.50
Use Systems Measures & Models	10	0.29	2.89	3.93	0.08	3.36	3.39
Inspire Integrative Learning	23	0.22	3.09	3.93	0.05	3.28	3.38
Foster Systems Planning & Evaluation	9	0.28	2.80	3.72	0.08	3.22	3.30
Show Potential of Systems Approaches	11	0.45	2.41	3.76	0.20	3.44	3.25
Explore Systems Paradigms & Perspectives	15	0.38	2.30	4.00	0.14	3.17	3.19
Utilize System Incentives	14	0.32	2.41	3.56	0.10	3.02	3.05

Table 6.3 shows the summary statistics for the cluster bridging values. One item worth noting is the number of statements in the *Inspire Integrative Learning* cluster (N=23) and the *Explore Systems Paradigms and Perspectives* cluster (N=15). Representing 48% of the total statements, these two clusters have to do with learning more about systems thinking and educational initiatives to develop knowledge and understanding of systems thinking in public health. It is significant that so many of the statements that were generated were related to the educational needs associated with systems thinking. This may suggest that participants are unclear about many aspects of systems thinking. Statements such as those in the list below (that are contained in these two clusters) highlight the need for greater clarity of the systems thinking construct and for education and training programs for systems thinking in public health:

- *Develop and deliver a 'Systems Thinking 101' course for public health professionals*
- *Develop comprehensive education/training programs about systems thinking for practitioners, researchers, and communities that support learning about the language, values and norms in other parts of the system*
- *Develop comprehensive education/training programs about systems thinking for practitioners, researchers, and communities that support learning about the language, vales and norms in other parts of the system*
- *Develop comprehensive education/training programs about systems thinking for practitioners, researchers, and communities that support learning about the language, vales and norms in other parts of the system*
- *Incorporate training in systems thinking and modeling throughout entire educational system from elementary school through advanced graduate degrees*

- *A common language for systems thinking in public health (e.g., a glossary)*
- *Forums that facilitate collaborative learning and knowledge sharing about systems thinking and methods*
- *Multiple, geographically dispersed, Centers of Systems Thinking and Modeling excellence providing expert technical assistance*
- *International, national, regional, state, and local 'Learning Collaboratives' about systems thinking and modeling*
- *Publication of more systems thinking and modeling work in mainstream public health journals and public health web forums*

Appendix 6C lists statements by cluster, average ratings for each statement, and the average rating for each cluster.

Table 6.3: Cluster Bridging Values Summary Statistics

Cluster Name	Statement Count	Std. Dev.	Min.	Max.	Variance	Median	Avg.
Expand Cross-Category Funding	10	0.05	0.38	0.54	0.00	0.47	0.46
Support Dynamic & Diverse Networks	8	0.15	0.32	0.85	0.02	0.70	0.64
Use Systems Measures & Models	10	0.09	0.20	0.52	0.01	30.5	0.34
Inspire Integrative Learning	23	0.11	0.00	0.36	0.01	0.15	0.16
Foster Systems Planning & Evaluation	9	0.18	0.42	1.00	0.03	0.73	0.73
Show Potential of Systems Approaches	11	0.05	0.18	0.36	0.00	0.24	0.27
Explore Systems Paradigms & Perspectives	15	0.14	0.31	0.72	0.02	0.44	0.48
Utilize System Incentives	14	0.08	0.27	0.53	0.01	0.39	0.40

Reliability of the Concept Map

One question about the data is whether the participant sorting aggregates are reliable. Trochim[183] explains how reliability in concept mapping differs from traditional reliability measures:

> The traditional theory of reliability typically applied in social research does not fit the concept mapping model well. That theory assumes that for each test item there is a correct answer that is known a priori. The performance of each individual is measured on each question and coded correct or incorrect. Data are typically stored in a rectangular matrix with the rows being persons and the columns test items. Reliability assessment focuses on the test questions or on the total score of the test. That is, we can meaningfully estimate the reliability of each test item, or of the total score.
>
> Concept mapping involves a different emphasis altogether. There is no assumed correct answer or correct sort. Instead, it is assumed that there may be some normatively typical arrangement of the statements that is reflected imperfectly in the sorts of all members who come from the same relatively homogeneous (with respect to the construct of interest) cultural group. The emphasis in reliability assessment shifts from the item to the person. For purposes of reliability assessment, the structure of the data matrix is reversed, with persons as the columns and items (or pairs of items) as the rows. Reliability assessment focuses on the consistency across the assumed relatively homogeneous set of participants. In this sense, it is meaningful to speak of the reliability of the similarity matrix or the reliability of the map in concept mapping, but not of the reliability of individual statements.[183]

He then presents six different ways to establish reliability in concept mapping (structured conceptualization). One of the methods suggested by Trochim, called the "Split Half Reliability Test" was used in this study. Trochim[183] describes this method as follows:

> The set of sorts from each project was randomly divided into two halves (for odd-numbered participant groups, one group was randomly assigned one more person than the other). Separate concept maps were computed for each group. The total matrices, T_A and T_B, for each group were correlated and the Spearman-Brown correction applied to obtain r_{SHT}.

The results of the Split Half Reliability Test were 0.7207 and 0.8377 after the Spearman-Brown correction was applied. Table 6.4 shows Trochim's[183] descriptive statistics for reliability estimates of r_{SHT} over 33 concept mapping studies.

Table 6.4: Descriptive Statistics for Split Half Reliability Estimates over 33 Projects

	r_{SHT}
Number of Projects	33
Mean	0.83330
Median	0.84888
Minimum	0.72493
Maximum	0.93269
Standard Deviation	0.05485

The results of the Split Half Reliability Test and the descriptive statistics across a range of studies show that the aggregate participant sorts in this study are reliable to a high degree.

Interpretation of Importance Ratings

The mean importance ratings for each cluster were shown in Table 6.2. The distribution of ratings within and between clusters are shown visually in Figures 6.6 and 6.7. For ease of explanation, each cluster was given a number, shown in Table 6.5.

Table 6.5: Number Assignments for clusters

1	Foster Systems Planning & Evaluation
2	Expand Cross-Category Funding
3	Support Dynamic & Diverse Networks
4	Use Systems Measures & Models
5	Utilize System Incentives
6	Explore Systems Paradigms & Perspectives
7	Show Potential of Systems Approaches
8	Inspire Integrative Learning

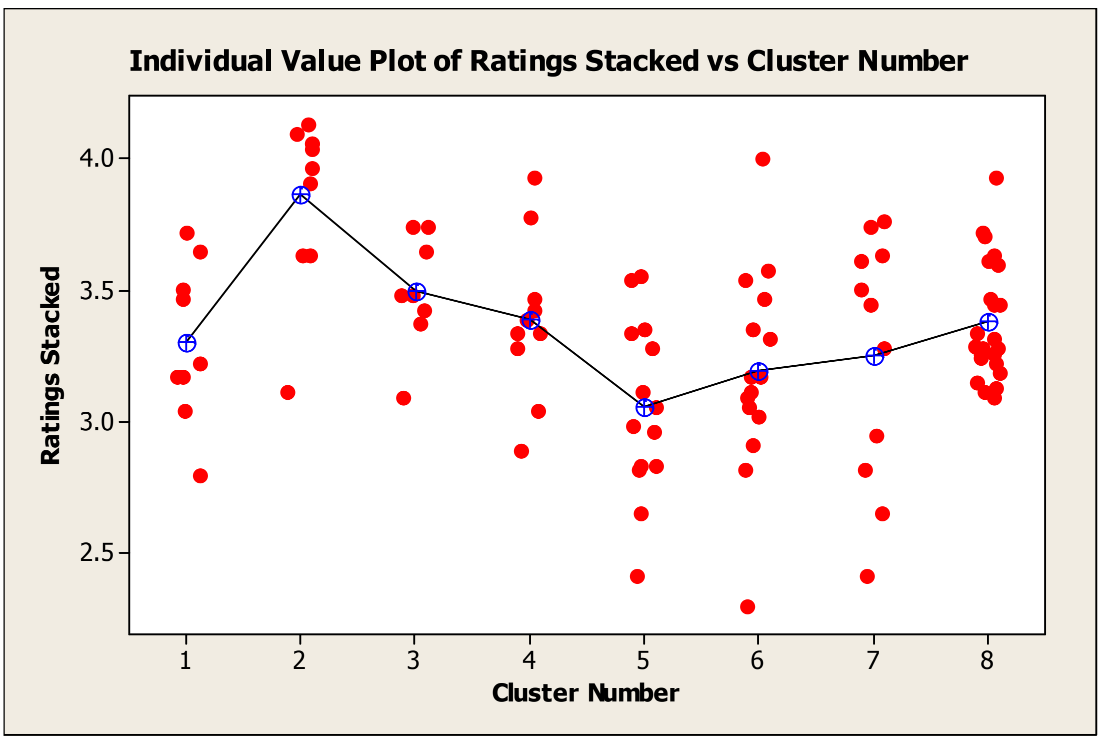


Figure 6.6: Individual Value Plot of Ratings Stacked vs Cluster Number

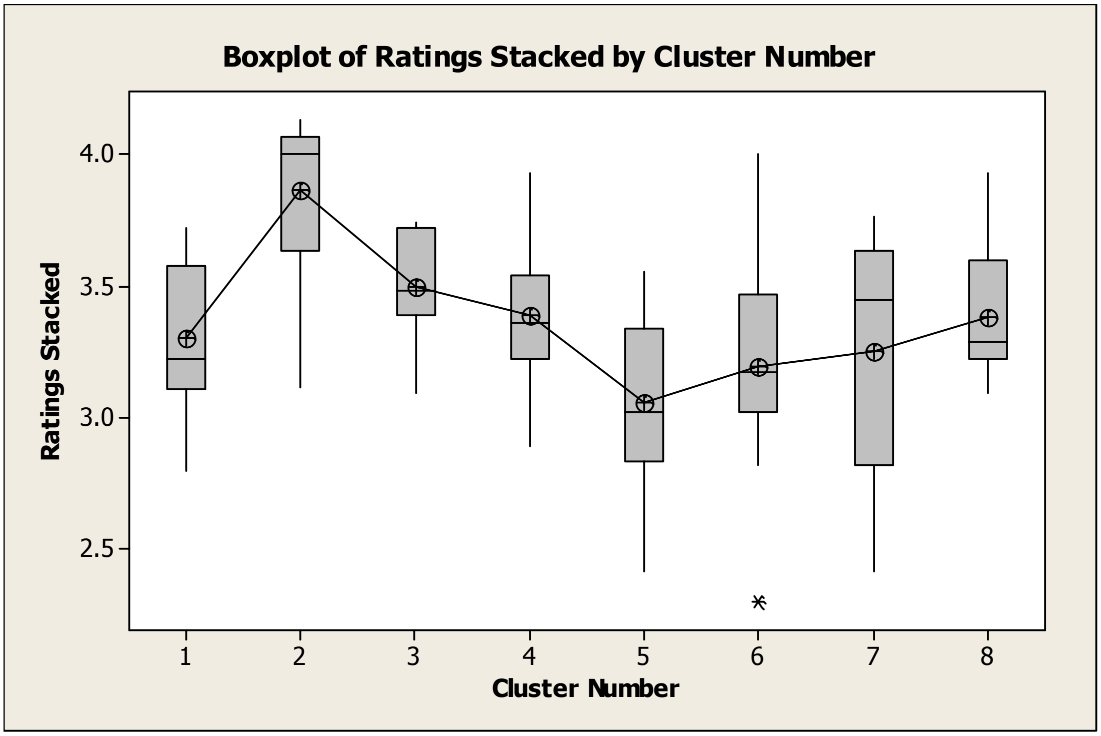


Figure 6.7: Boxplot of Ratings Stacked by Cluster Number

To further interpret the relative ratings, Tukey's multiple comparison method was used to test whether differences in the mean ratings reached statistical significance (α=0.05). The results of Tukey's multiple comparisons test are shown in Table 6.6.

Table 6.6: Significance Between Clusters in Tukey Multiple Comparisons Test

	2	**3**	**4**	**5**	**6**	**7**	**8**
1	0.007**	0.919	0.999	0.612	0.992	1.000	0.999
2		0.276	0.031**	0.000**	0.000**	0.001**	0.004**
3			0.996	0.050**	0.391	0.763	0.985
4				0.215	0.826	0.982	1.000
5					0.939	0.782	0.072
6						1.000	0.674
7							0.966

The primary finding of the multiple comparisons is that the only statistically significant differences in mean importance ratings were between Cluster 2 (Expand Cross Category Funding) and the remaining clusters. Conversely (and equally interesting), was the fact that, with one exception, there were no significant differences in mean importance ratings between Clusters 1, 3, 4, 5, 6, 7, and 8. The sole exception was that Cluster 3 was significantly different from Cluster 5. These results can be interpreted as indicating three "importance" groups, as shown in Figure 6.8, where Cluster 2 has the highest average rating, Clusters 1, 3, 4, 6, 7, and 8 are essentially a single super-cluster in the middle rating, and Cluster 5 (Utilize System Incentives) has the lowest average rating. It should be noted, however, that all cluster means fall between 3.0 and 4.0 on a 1–5 rating scale.

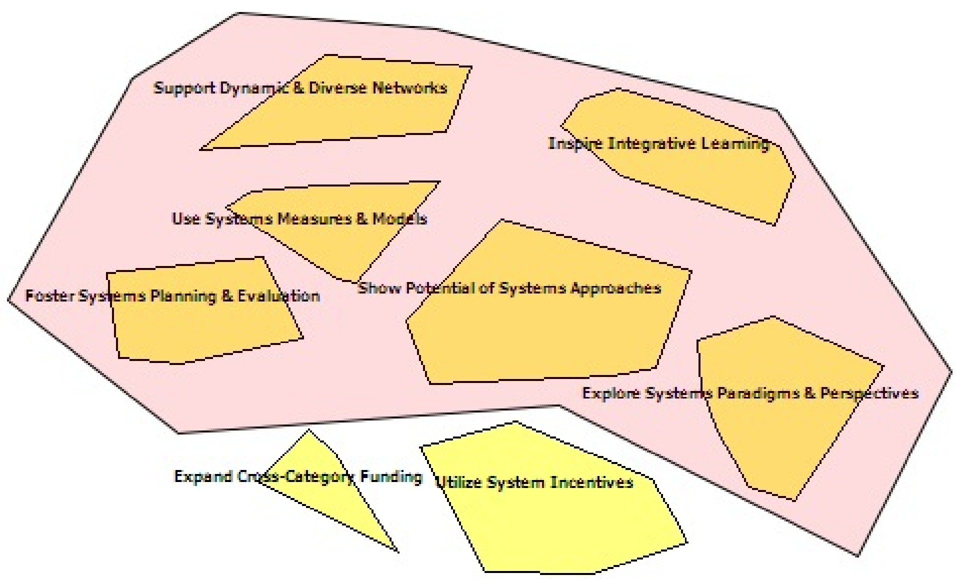


Figure 6.8: Cluster Map after Tukey Multiple Comparisons Test

One interpretation of the importance ratings is that the sample did not differentiate to a high degree the various clustered statements in terms of importance.

This may be because participants felt that most of the statements were of general importance as implementation challenges. Another possible interpretation is that the systems thinking construct is sufficiently vague that participants had difficulty differentiating between clusters with respect to importance.

Other Findings

One of the results that emerged from this research was a new perspective on the structured conceptualization methodology in which clusters are rendered as independent conceptual agents. This idea is born of the complex adaptive systems literature and is elaborated upon in Trochim.[176, 183, 184] By viewing the clusters as conceptual agents interacting with each other, managers and leaders in public health can utilize this map as a simple rule set for managing systems thinking initiatives in public health. Future research into human simulations using simple rules is one outgrowth of this research and has currently been submitted for funding to NIH. Table 6.7 illustrates how such an interpretation has cluster names interacting in such a way as to produce new questions that could be used by practitioners to manage systems initiatives.

Table 6.7: Clusters as Interacting Agents

	Expand Cross-Category Funding	Support Dynamic & Diverse Networks	Use Systems Measures & Models	Inspire Integrative Learning	Foster Systems Planning & Evaluation	Show Potential of Systems Approaches	Explore Systems Paradigms & Perspectives	Utilize System Incentives
Expand Cross-Category Funding	How can cross-category funding be used to expand the practice of cross category funding?	How can dynamic and diverse networks expand cross category funding?	How can systems measures and models be used to expand cross category funding?	How can integrative learning lead to the expansion of cross category funding?	How can systems planning and evaluation expand reinforce cross category funding?	How can showing the potential of systems approaches expand cross category funding?	How can exploring systems paradigms and perspectives lead to expanded cross category funding?	How can the use of system incentives increase cross category funding?
Support Dynamic & Diverse Networks	How can cross-category funding support dynamic/diverse networks?	How can dynamic and diverse networks be used to support dynamic and diverse networks?	How can systems measures and models be used to support dynamic and diverse networks?	How can integrative learning lead to support of dynamic and diverse networks?	How can systems planning and evaluation encourage outcomes that require dynamic and diverse networks?	How can showing the potential of systems approaches increase the dynamics and diversity of networks?	How can to support dynamic and diverse networks?	How can the use of system incentives increase dynamic and diverse networks?
Use Systems Measures & Models	How can cross-category funding incentivize the use of systems measures and models?	How can dynamic and diverse networks better use systems measures and models?	How can systems measures and models be used to inform systems measures and models?	How can integrative learning increase the use of systems measures and models?	How can systems planning and evaluation use systems measures and models to model and measure outcomes?	How can showing the potential of systems approaches increase the use of systems measures and models?	How can exploring systems paradigms and perspectives lead to increased use of systems measures and models?	How can the use of system incentives increase the use of systems measures and models?

Table 6.7 (Continued)

	Expand Cross-Category Funding	**Support Dynamic & Diverse Networks**	**Use Systems Measures & Models**	**Inspire Integrative Learning**	**Foster Systems Planning & Evaluation**	**Show Potential of Systems Approaches**	**Explore Systems Paradigms & Perspectives**	**Utilize System Incentives**
Inspire Integrative Learning	How can cross-category funding inspire integrative learning?	How can inspire integrative learning?	How systems measures and models be used to inspire integrative learning?	How can integrative learning be used to increase integrative learning?	How can systems planning and evaluation incorporate integrative learning into program models and outcomes?	How can showing the potential of systems approaches inspire integrative learning?	How can exploring systems paradigms and perspectives lead to more integrative learning?	How can the use of system incentives increase the practice of integrative learning?
Foster Systems Planning & Evaluation	How can cross-category funding foster systems planning and evaluation?	How can foster systems planning and evaluation?	How can systems measures and models be used to foster systems planning and evaluation?	How can integrative learning foster systems planning and evaluation?	How can systems planning and evaluation inform systems planning and evaluation at a meta-analytical level?	How can showing the potential of systems approaches foster systems planning and evaluation?	How can exploring systems paradigms and perspectives foster systems planning and evaluation?	How can the use of system incentives increase systems planning and evaluation?
Show Potential of Systems Approaches	How does cross-category funding be used to show the potential of systems approaches?	How can to show the potential of systems approaches?	How can systems measures and models be used to show the potential of systems approaches?	How can integrative learning demonstrate the potential of systems approaches?	How can systems planning and evaluation be used to show the potential of systems approaches?	How can studying the potential of systems approaches increase our ability to show the potential of systems approaches?	How can exploring systems paradigms and perspectives show the potential of systems approaches?	How can the use of system incentives increase the ability to show the potential of systems approaches?

Table 6.7 (Continued)

	Expand Cross-Category Funding	**Support Dynamic & Diverse Networks**	**Use Systems Measures & Models**	**Inspire Integrative Learning**	**Foster Systems Planning & Evaluation**	**Show Potential of Systems Approaches**	**Explore Systems Paradigms & Perspectives**	**Utilize System Incentives**
Explore Systems Paradigms & Perspectives	How can cross-category funding be used to explore systems paradigms and perspectives?	How can to explore systems paradigms and perspectives?	How can systems measures and models be used to explore systems paradigms and perspectives?	How can integrative learning help people to explore systems paradigms and perspectives?	How can systems planning and evaluation be used to explore systems paradigms and perspectives?	How can showing the potential of systems approaches lead more people to explore systems paradigms and perspectives?	How can systems paradigms and perspectives inform our exploration of systems paradigms and perspectives?	How can the use of system incentives increase the number of people who explore systems paradigms and perspectives?
Utilize System Incentives	How can cross-category funding support the utilization of systems incentives?	How can the utilization of systems incentives?	How can systems measures and models be used to encourage utilization of systems incentives?	How can integrative learning be used to show people how to better use systems incentives?	How can systems planning and evaluation incorporate systems incentives into program models and outcomes?	How can showing the potential of systems approaches increase the use of systems incentives?	How can exploring systems paradigms and perspectives lead to the utilization of systems incentives?	How can the use of system incentives incentivize the use of systems incentives?

As an explorative empirical study in a vast field about a complex topic, the interpretation of results should proceed cautiously and conservatively. The research herein offers a snapshot of how one group of public health practitioners conceptualize systems thinking and its implementation challenges.

The difference between demographic groups was not significant (this data was not included herein). Cluster ratings on the whole were relatively homogenous and lacked statistical significance for all but two clusters. Cross-category funding (a cluster) was shown to be significantly different from the other clusters and had the highest average rating of all of the clusters. This may be because the general tendency is for people to rate funding high, or it may indicate a particular need based on the unique challenges of systems thinking implementation.

It is also clear that no statistical conclusions with respect to the construct of systems thinking can be drawn from these findings. Given the obvious ambiguities in the literature around the construct of systems thinking, however, one potential interpretation of the lack of variability is that "variance got sucked up" in the construct of systems thinking and various other ambiguous terminology. That is, the variation was built into the statements and cluster names themselves based on the ambiguity of terms. Five of the 8 clusters contained the word "systems" in their title, and 62% (N=62) of the 100 statements included the term. If it is true that the construct of systems thinking is vague or that it has multiple meanings, this may account for the lack of significance in the ratings or the high degree of noise in some aspects of this study. The significant ambiguities found in the literature, combined with the use of so many different "synonyms" for systems thinking in the statements, may point to the source of this noise. None of these interpretations is statistically conclusive from the results, but the results do not controvert such interpretations, either.

The map was shown to have high reliability. Based on this sorting, 48% of the statements generated fell within two groups having to do with developing knowledge and understanding of systems thinking. This, too, points to the possibility that people are seeking greater clarity about the systems thinking construct.

Chapter Seven

Discussion and Conclusion

This chapter is a deeper discussion of the various conclusions that may be drawn from the critical review of the literature and the research data. From these various conclusions a theory and future research is suggested. A summary of these findings is found in Table 7.1.

Table 7.1: Summary of Analysis and Findings

Test/Analysis	**Interpretation**
Critical Literature Review	Significant ambiguities and practitioner adoption; systems thinking is a conceptual framework
Methodological Review	High ratio between descriptive and empirical studies; construct validity problems in the few existing empirical designs
Split Halves Reliability Test	Test results and the descriptive statistics across a range of studies show that the aggregate participant sorts in this study are reliable to a high degree.
Tukey Multiple Comparisons Test	Low significance in ratings; One interpretation may be that the systems thinking construct is sufficiently vague that participants had difficulty differentiating between clusters with respect to importance
Statement Analysis	Two clusters, representing 48% of the total statements, have to do with learning more about systems thinking and educational initiatives to develop knowledge and understanding of systems thinking. This may suggest that participants are unclear about many aspects of systems thinking.

Several interpretations are proposed. Central to each of these interpretations is the perceived need for greater clarity of the systems thinking construct. The relation and differentiation between systems thinking and other related terms is discussed. It is also proposed that systems thinking scholars and educators are primarily responsible for developing new, more clearly defined mental models, theories, and curricula for systems thinking. The difference between a systems thinking construct and a definition is discussed, and it is proposed that while a definition is likely futile, a clearer construct is necessary and possible. An "ideal" is proposed that creates a framework for what a theory of systems thinking might look like and how it might be valuable. Finally, a "minimal concept theory" of systems thinking is proposed and explained using a real-world system as an example.

What can be concluded from this explorative study of systems thinking? There is more noise than signal. Whether this noise is caused by the ambiguities in the systems thinking construct, as was proposed in the literature review, cannot be statistically determined. However, the statistical findings do not controvert such a hypothesis, and a qualitative analysis is suggestive. It is plausible, if not likely, that the noise in the system is due to many competing factors, one of which, perhaps significantly, is the many degrees of freedom permitted by the various ambiguities in the systems thinking construct.

The scholarly review of the literature and the analysis and interpretation of the research data can be viewed as alternative "snapshots" in an emerging construct of systems thinking. From the literature review, it can be seen that systems thinking is as important as it is ambiguous. Deming, one of the great scholars of management "identified systems thinking as one of four sources of 'profound knowledge' along with psychology, statistics and Plan-Do-Check-Act (PDCA)."[185(p155)] Precisely because systems thinking is perceived as so important by so many, these ambiguities must be remedied.

The ambiguities that exist in the systems thinking construct also provide opportunities for future research and clarification. This explorative research into how a relatively homogenous group of scholars and practitioners perceive systems thinking, and about the challenges associated with implementing it, leads to more questions than it does answers. These "first" snapshots hint at a fascinatingly complex storyline, but the resolution is very low. More research that makes systems thinking the object of investigation is needed. This type of research will be of general importance. That is, it will be important not only to public health practitioners but also to those in numerous other fields that hope to implement systems thinking. In this regard, it is not the job of practitioners in other fields *per se* to investigate systems thinking. Instead, it is the job of the systems thinking community of scholars.

This final chapter offers some thoughts to the fields of systems thinking and education in the hope that they provide at most a contribution, and at least, "something to bump up against" as we collectively refine our knowledge of systems thinking.

First, the motivation to learn more about and to implement systems thinking may exist because people believe there is a need to *think differently* about their problems or challenges. This need has been referred to here as the "crisis of conceptualization." It is an important first step in clarifying the systems thinking construct because it explains that people are not seeking new research methods, new science, new ideas or concepts or theories, or even new activities *per se*. Broadly speaking, what these people seek is *new thinking*. Of course, systems methods, sciences, ideas, and theories are very related and will be a part of any education in systems thinking.

Second, as the systems thinking construct becomes more clearly developed, it will also be important to differentiate between it and its related constructs: systems approaches, systems sciences, systems theories, and systems ideas. The term "construct" has been deliberately used throughout in place of the term "definition." This is because semantic debate about the *definition* of systems thinking tends to deteriorate rapidly as well as vapidly. Instead, various related constructs that are currently used alternatively to mean both the same and different things must become more meaningfully differentiated. In simple terms, one might think of this process as a Venn diagram in which there is overlap and difference, containment and relatedness. In more complex terms, this suggests that a theory or competing theories of systems thinking (different from a theory of systems) must be developed. In short, what is needed is not a dictionary definition of systems thinking, but a valid construct that can be reasonably studied, operationalized, measured, or evaluated. These activities will move the field forward and, more important, make systems thinking less challenging to implement.

Third, the relationship between implementation challenges and construct validity must be made more explicit. As the popularity of and desire to implement systems thinking in practice grows—and it is growing—the need for theoretical clarity also increases. It is our job—we in the field of systems thinking—to set to work on the task. Furthermore, it is our job—we in the field of education—to increase the efficacy with which we facilitate learning about systems thinking. The clear purpose for systems thinking educators is clarity of concept and efficacy of delivery. Where systems thinking is concerned, the clarity of the construct is one of the central challenges to implementation.

Fourth, there is a great deal of noise. More research is needed. We can learn much from and make incremental progress by following the "medical model" of research, in which research is staged in phases (e.g., exploratory, correlational, experimental, implementational) according to the characteristics of the phenomenon. This study is an exploratory study to find out more about systems thinking and its challenges. The map itself was reliable, but the ratings contained a great deal of noise. More studies are needed that find innovative methods and techniques for separating the signal from that noise. With additional explorative studies in systems thinking, we may be better prepared to conduct correlational studies, and then experiments and hypothesis testing, and, finally, implementation studies.

We should explore three themes in greater depth: namely, (1) the relation of systems thinking to other systems terminology, (2) the role of education in systems thinking, and (3) the need for a theory of systems thinking that is aligned with the counterclaims that were addressed in the literature review.

The Relation of Systems Thinking to Other Systems Terminology

A recent email exchange by a few of the participants of the EVAL-SYS email discussion group (a discussion group dedicated to a better understanding of systems thinking and evaluation) offers a poignant example of the ambiguity with which systems terminology is used. In a relatively short exchange of 14 emails over 6 days, a derivation of systems-X was used 81 times. Some of these uses included:

> Systems based approaches, a “system,” systems theory, systems based inquiry, systems thinking approach, systems based inquiry, a “systems” perspective, “systems” studies, systemic study , “system-wide,” “systems” tools, systems analysis, systems theory, systems approach, system dynamics, soft systems method, complex adaptive systems, critical systems, Systems field, idea of systems, the systems field, thinking about systems, systems frameworks, cluster of system theories, the so-called “soft” and “critical” systems areas, components of a “system,” system’s diagram, soft systems methods, systems concepts, “critical systems thinking,” “in systems terms,” systems results and systems impacts, systems change, systems perspective, systems level, “sub-systems,” “surrounding systems,” broader systems changes, systemic approach, a “system wide intervention, systems thinking tools as methods, think systematically, systems thinking tools, complex systemic analysis, system shifting, super or sub-system, a complex system, respiratory system, soft systems analysis, a systems based analysis, and even, “systemy thing.”[186]

To an expert eye, this exchange was, at best, convoluted, and to the novice it would have likely been incomprehensible. The term “systems thinking” appeared many times and was alternatively used to have both the same and different meanings from other terms. Yet, while the term is used casually to mean any number of things, other curious uses imply that it is somehow different. One contributor wrote, "the former I'd classify as "network thinking" and the latter as "systems thinking," while another wrote, "systems based approaches (a.k.a. systems thinking)," and yet another wrote, "systems based approaches (and the thinking that goes with it)." The wide usage of synonymous terminology, and the subsequent differentiation of these terms, corroborates the ambiguous nature of this dialogue, which is unfortunately characteristic of the field of systems thinking. It has been proposed herein what some of these discussion contributors only allude to in their comments—that systems thinking is a conceptual endeavor and is different from systems approaches, sciences, theories, and ideas. A great deal of work lies ahead in developing taxonomies of systems methods and accountings of systems theories and their lesser concepts, and assessing the patterns of thought that make up systems thinking. One goal of the work herein is to provide adequate differentiation of systems thinking as a conceptual phenomenon. This distinction will in turn help in differentiating other constructs that are important to the field. Figure 7.1 illustrates the popular metaphor from the field of system dynamics that beneath various events, behaviors, and structures lie deep mental models—conceptual models of how we think.

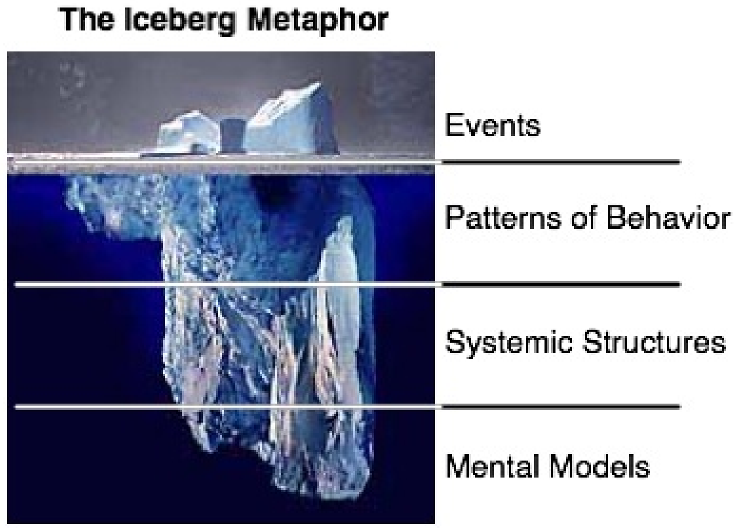


Figure 7.1: The Iceberg Metaphor

Figure 7.2 is a Venn diagram of the relationships between the most prevalent terms: Approaches, sciences, theories, methods, ideas and thinking. The Venn diagram illustrates how there is some overlap between, for example, systems methods and systems concepts. It shows that general systems theory is contained within "Theories of Systems," which are specific epistemological theories about how ontological systems work. These can be differentiated from ontological systems theories such as complexity theory or chaos theory, which are specific theories about how specific types of systems behave.

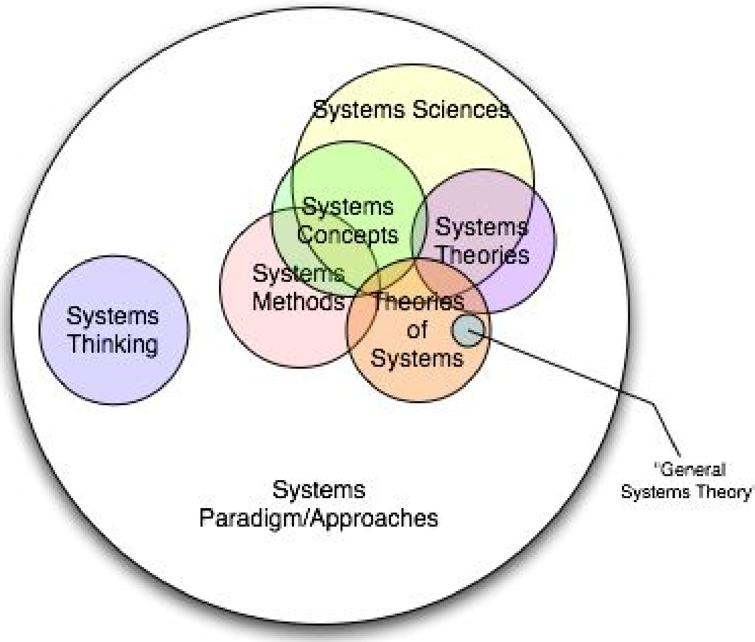


Figure 7.2: Venn Diagram of Related Terms

The systems sciences are a loosely affiliated group of fields and sciences that are defined by their respective scientists, conferences, and journals as well by as shared ideas. Systems concepts are merely ideas that might come from various areas but that contribute to our understanding of how a particular system behaves or how systems in general behave. Systems methods are "step-wise" processes used to study systems or that explicitly use systems theories, concepts, or thinking. Any one of these areas can be called a systems approach—the most general and inclusive of the terms. Finally, as has been stated previously, systems thinking represents a very different type of phenomena. As the iceberg metaphor illustrates, systems thinking is the (often implicit) patterns of thinking or "habits of mind" that make these various areas "feel" like similar endeavors. Because (1) systems thinking is so often an implicit activity; (2) it is the foundation for all of these other activities; and (3) it is currently mired in ambiguity, there is a pressing need for a theory of systems thinking. Before such a theory is proposed, however, it is important to situate systems thinking in terms of an educational imperative.

The Role of Systems Thinking Scholars and Educators

The ambiguity of the systems thinking construct is one of the primary challenges of implementing systems thinking in practice. One might generalize this finding to any domain in which people are trying to implement systems thinking (e.g., business, education, evaluation, etc.). This generalization is valid because the challenges wrought by the various construct ambiguities are not to be found in public health *per se*, but are central to the debate within the field of systems thinking itself. If the field of scholars who study systems thinking cannot devise a valid construct for systems thinking and differentiate it from the other important terminology in the field (e.g., approaches, science, theories, concepts, methods), then one would expect that practitioners and researchers from other fields will have even greater difficulty doing so.

If systems thinking is, as it has been presented herein, a conceptual phenomenon, rather than a scientific or methodological one, then it is clear that educators play a central role in its dissemination. Here again, the term "educators" refers to both formal and informal pedagogues and adult educators (andragogues). Figure 7.3 illustrates the many "feedback loops" in the causal sequence in which systems thinking plays a significant role.

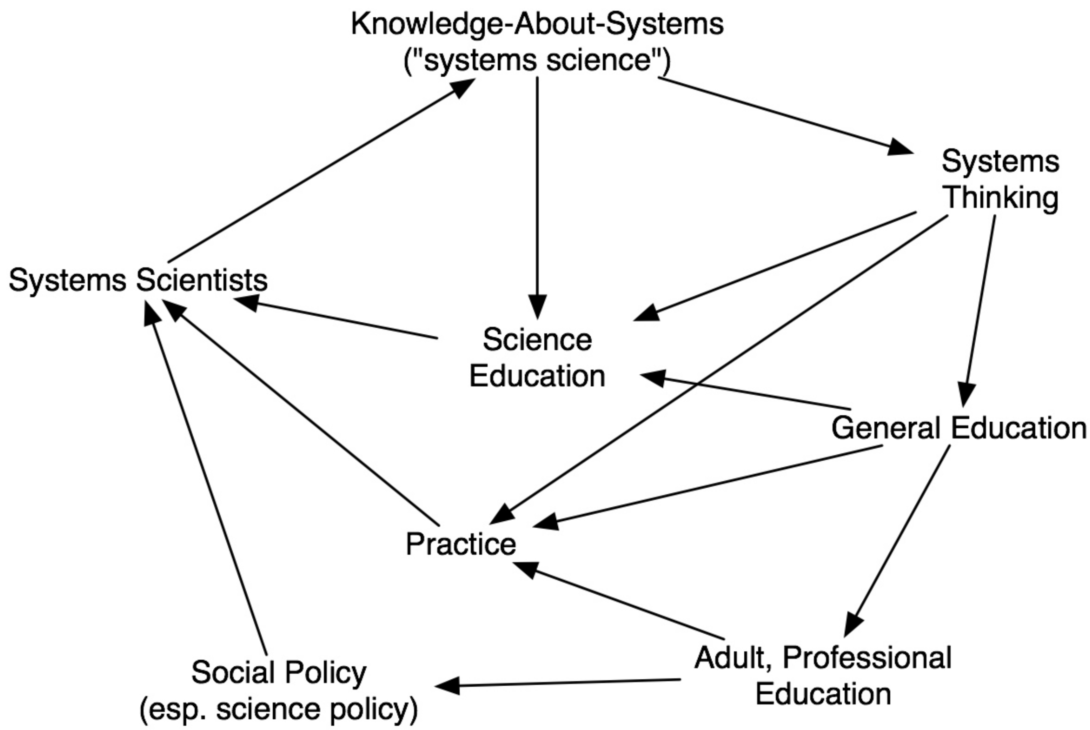


Figure 7.3: The Educational Role of Systems Thinking

The differentiation between systems thinking and knowledge-about-systems has already been made. Systems thinking is informed by knowledge-about-systems and, as Figure 7.3 illustrates, this influence "feeds back" to knowledge-about-systems through a number of different channels. First, where systems thinking is included in general education it will become part of the "habits of mind" of the general population of students, some of whom will become scientists (where they may be introduced to more advanced forms of systems thinking and systems concepts), and some of whom will become practitioners of all kinds. Therefore, a clear construct of systems thinking may have a dramatic positive impact on practice; conversely, an ambiguous construct of systems thinking will have dramatic negative impact on practice. The impact of systems thinking on practice will also influence the kinds of problems scientists attempt to solve because practitioners will be searching for answers to different types of questions. Some of the student population from both general and science education will end up in positions that will influence social, economic, educational, and scientific policy. With a clear understanding of systems thinking from their days as students, they will in turn influence scientists, for example, by devising certain criteria—based on systems thinking—for request for proposals. This sequence of events can be called the traditional role of systems thinking in education. As Figure 7.3 illustrates, systems thinking can play a pivotal role in the education of adults and professionals. This type of education is essential, for example, in the current public health system. As this study shows, there is a significant gap between the motivation of public health professionals to implement systems thinking and their understanding of the construct. Adult and professional education in systems thinking is desperately needed before premature implementation efforts lead to failures that are framed retroactively as weaknesses of systems thinking rather than as failures in systems thinking education. It is the job of educators then, to work with those in the systems thinking field to push them to more clearly articulate the construct of systems thinking and, then, to develop useful curricula for K-Adult populations.

Part of this educational effort involves meeting learners where they are and then moving them toward a more advanced understanding of systems thinking. Figure 7.4 illustrates such a progression for practitioners in any field. Initially, practitioners will desire quick advice on how to implement systems thinking in their field. At some point they may seek out specific methods or want to learn certain concepts from the systems sciences (knowledge-about-systems). But education does not merely, as the saying goes, “give a man a fish so that he can eat for a day,” it must also endeavor to “teach that man to fish” so that he might “eat for a lifetime.” As practitioners learn more about the things they can do, the methods and concepts and theories of systems, educators must take them a step further to develop genuine systems thinking—to recognize patterns of systems thinking and then to develop a mental model of what it is.

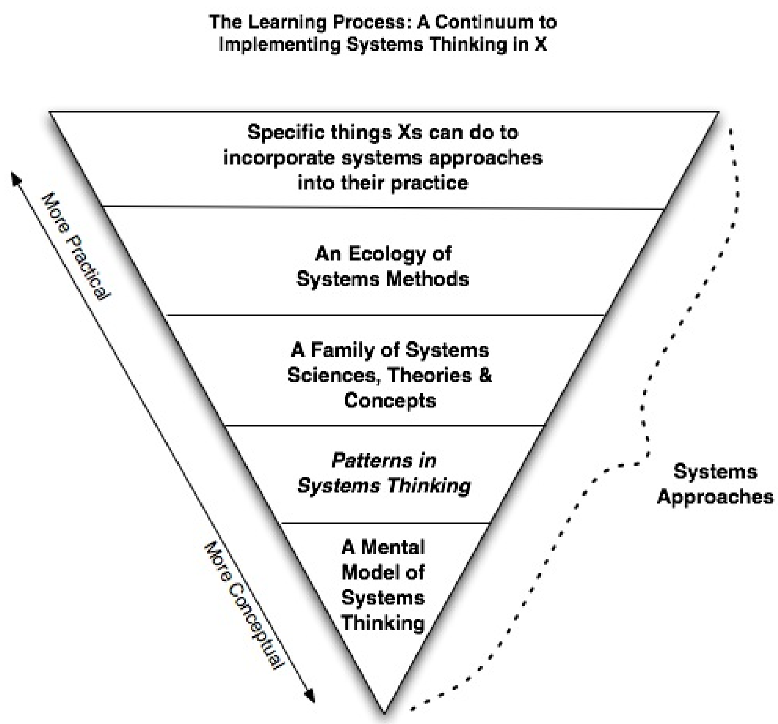


Figure 7.4: Toward the Ability to Systems Think

Three issues cause the bulk of immediate future work in systems thinking to be situated in the fields of education and systems thinking (as opposed to public health or other places where it is being implemented): (1) that the ambiguous construct of systems thinking leads to implementation challenges, (2) that the conceptual nature of systems thinking centers it squarely within educational practice, and (3) that education that begins with best practices and various systems ideas should progress toward the more general and conceptual ability to systems think. That is, the burden and the responsibility for developing a clear mental model of systems thinking and disseminating that model lies less with professionals in other disciplines, for example, and more with scholars of systems thinking and with educators.

A Mental Model of Systems Thinking, Not a Definition

Much has been discussed herein. There are—from the problems highlighted in the literature review and the challenges that emerged from the structured conceptualization research—numerous important tangents that one might take to their conclusion. Yet underlying any one of these important tangents is the problem of the ambiguous construct of systems thinking. It seems ill-advised to continue further without lessening the noise in this construct. A “definition” *per se* is not called for, as it is true that nearly every field struggles to find a definition of its flagship concepts. The field of evaluation, for example, would be hard pressed to define the term *evaluation.*[184] We do not need a *definition* of systems thinking. What is needed is a model, a framework, or even a theory of systems thinking. Not a theory of systems (as there are several of those) but a theory of systems thinking. Even if the theory is contested, even if it is incomplete, even if, as all models inevitably are, it is wrong; we need a theory of systems thinking. The current state of affairs is untenable, as there is nothing in the construct of systems thinking that one can “bump up against.” Because systems thinking is thought of by many to be so many things, because it is at once a method, a science, an idea, an approach, complexity, chaos, system dynamics, etc., there is little that cannot be included in the construct and. therefore, as the construct includes everything, it is meaningless.

This work has been an attempt to bring greater clarity to the construct of systems thinking. First, the literature was reviewed to learn more about what systems thinking is and what it cannot possibly be given our knowledge-about-systems. Second, the conceptual nature of systems thinking was differentiated from the methodological nature of systems methods, the scientific nature of the systems sciences, and the ontological nature of systems theories and ideas. If one needs a broad term to encompass each of these related areas, then *systems approaches* is the likely candidate. But let us not lose the important "habits of mind" that make up systems thinking simply because we seek a broad, inclusive term. Third, it was demonstrated that the ambiguity of the systems thinking construct may yield implementation challenges that lead us to question whether implementation is premature before a workable construct is offered. Fourth, the linkage was made between the fields of systems thinking and education as partners in future efforts toward construct clarity and dissemination.

The Middle Way Criteria for a Mental Model of Systems Thinking

Not all systems thinking scholars will agree with the counterclaims made in the literature review. For example, many people of the systems-orientation persuasion will vehemently disagree with the notion that emergence is merely a term used to hide a lack of knowledge; that is, that emergence is really no different from not recognizing some set of causal relationships, either because such relationships are hard to detect or because one believes there is little value in doing so. An alternative reason to advocate for emergence is that it coincides with metaphysical explanations. Similarly, some systems thinking scholars will take issue with the claim that systems thinking is necessarily reductionistic as well as holistic. Some argue that it is the antithesis of reductionism.

But there *are* principles of systems thinking that most people tend to agree on within in the literature. Three such principles are that systems thinking involves some kind of what Midgley calls "boundary critique."[16, 187-190] That is, in order to systems think one must explicitly set boundaries (however arbitrary) that cause some things to be excluded from consideration and others to be included. The second widely held principle is that systems thinking involves multiple perspectives. Whether what is meant by perspective is that multiple stakeholders must be involved or that multiple levels of size (organization, organism, organ, etc.) must be considered, the notion that one must “look at the issue from numerous perspectives” is widely accepted. In the social sciences, a third principle that is widely held is that systems thinking involves “putting things in context.” Unfortunately, context is such a vague term that it borders on being meaningless—a catch all for everything. In this way, context is to the social sciences what emergence is to the physical and natural sciences. There are likely many, many interactions occurring within the system of interest that lead to this emergence or context.

Remember from a previous discussion that a pluralist, integrative, necessary and sufficient, or PINS, theory of systems thinking is an important future development. A PINS theory of systems thinking must therefore meet certain criteria. These criteria will be called the “middle way criteria” because systems thinking must balance the competing explanations (i.e., reductionism and holism). A middle way criteria is, like it sounds, an optimal set of criterion that a systems thinking model might meet. That is, it would be nice to develop a theory that is capable of reconciling these divergent claims about systems thinking with claims for which there is more agreement. A model that meets the *middle way criteria* might:

- leave the original dogma to be anti-reductionist and instead pursue a middle way that balances holism and reductionism; a model that is both discrete and continuous;
- not embrace the easy answers offered by notions of *emergence* and *context* and instead strive to identify the actual workings of things even if identification is slow going and incremental;
- embrace many different types of systems: linear ones, mechanical ones, organic ones, ecological ones, physical, natural and human ones and even, conceptual systems;

- not settle on the most popular version of systems thinking but seek to find a new version that encompasses general patterns or habits of mind that work for all systems, not just systems that that fit a specific model (such as feedback and stocks and flows).

Pursuing this "middle way" is the challenge that faces the systems thinking community and the challenge that will bring the greatest rewards if we face it head on despite all of its sundry problems and perceived impossibilities. The "middle way" attempts to reconcile a number of the conflicts and perceived paradoxes inherent in systems thinking. In other words, it takes the "middle way" between, for example:

- reductionism and holism
- realism and constructivism
- positive and negative
- form and function
- structure and dynamics
- relational/proximal and categorical/discrete

What would a theory of systems thinking—built upon these criteria—do? The short answer is that it would satisfy the criteria itself. It would reconcile the conflict between reductionism and holism. It would provide a model—however complex—for dealing with the black box that is emergence and context. It would help people work on the system of their interest without subjecting it to false metaphors; that is, it would allow people to meet the system on its own terms, mechanical, biological, or otherwise. It would help people to systematically and methodically determine boundaries and to view various systems from multiple perspectives. It would give educators a model to work with when someone asks, "What is systems thinking?" or

"How do I learn to systems think?" And, last but not least, it would provide a powerful conceptual tool for solving problems and alleviating not only the various crises we face but also the underlying crisis of conceptualization.

Creating such a model is a tall order—perhaps impossible. But if Deming is right about systems thinking as a powerful force, then it behooves us to try, if for no other reason than to give scholars of systems thinking something to "bump up against."

The Minimal Concept Theory of Systems Thinking (MCT/ST)

A simple-complex and fractal "minimal concept theory" of systems thinking is offered. It is necessary to explore in greater depth what is meant by each of these terms. By simple-complex, it is meant that the process of systems thinking is based on simple rules despite the fact that the outcomes may be terribly complex. Nobel laureate Murray Gell-Mann, speaking about complex adaptive systems, explains (emphasis his):

> What is most exciting about our work is that it illuminates the chain of connections between, on the one hand, the simple underlying laws that govern the behavior of all matter in the universe and, on the other hand, the complex fabric that we see around us, exhibiting diversity, individuality, and evolution. The interplay between simplicity and complexity is the heart of our subject.
>
> It is interesting to note, therefore, that the two words are related. The Indo-European root **plek*- gives rise to the Latin verb *plicare*, to fold, which yields simplex, literally once folded, from which our English word "simple" derives. But **plek*- likewise gives the Latin past participle plexus, braided or entwined, from which is derived *complexus*, literally braided together, responsible for the English word "complex." The Greek equivalent to *plexus* is πλεκτος (*plektos*), yielding the mathematical term "symplectic," which also has the literal meaning braided together, but comes to English from Greek rather than Latin.[57]

That conceptual systems are complex is *a priori*. That conceptual systems are highly adaptive is also *a priori.* One might reasonably argue that conceptual systems are the most adaptive and complex types of systems because the physical and natural constraints placed on the evolution of conceptual systems is significantly dampened (i.e., while the biological structures responsible for conceptualization do adhere to the physical laws, there is nothing stopping one from imagining a world without gravity, or one in which a zebra head is placed upon the body of a trout). Therefore, it is reasonable to conclude that conceptual systems are complex adaptive systems. And while these conceptual systems are not constrained by the laws of physics *per se*, as complex systems with considerable order they may reasonably be thought to be derivative of simple rules. A theory of conceptual systems might attempt to identify these simple rules.

Note that as we delve more deeply into what a model of systems thinking might look like, the lines between thinking and systems thinking become blurred. That is, it is difficult to differentiate between “systems thinking” and “thinking systems”; a *conceptual model* of systems thinking is, by definition, a thinking system or, more accurately, a conceptual system. That is, we are focused not on the ontological realities of existing systems but on systems of thinking and how these systems of thinking might be more “friendly” toward understanding ontological systems. Therefore, the line between thinking and systems thinking becomes much more fuzzy. The question is, what is the difference between systems thinking and thinking? It is suggested here that there is a real and pragmatic difference: a mind can have a systems thought without being a systems thinker. That is, systems thoughts may occur frequently but not consciously. This distinction may explain why so many “systems scientists” would never think to call themselves systems thinkers. To them, they are merely thinking about systems, and the net result is some systems thought, but it is not systems thinking. The central argument of this dissertation is that there are patterns to these systems thoughts, that underlying the factual knowledge of systems concepts are implicit and unconscious patterns that can be understood, turned into a schema or model, and developed and practiced on purpose. Systems thinking is a conscious, purposive act, whereas a systems thought may or may not be. Systems thinking is the conscious process of thinking in a methodical way by utilizing some set of patterns that universally underlie systems thoughts. This suggestion is very different from that made by most of the existing systems thinking literature, in which the construct is thought to be a taxonomy of systems concepts or methods.

Remember, too, from the review of the literature that no model of systems thinking can "violate" what is known about systems; if it does so, it is a special model not a general one. In addition, remember that a previously proposed definition for systems thinking (albeit very broad) was suggested that stated, "Systems thinking is thinking that is informed by knowledge-about-systems." It is important here to revisit this idea in the context of the proposed model. First, the proposed model of systems thinking is a general model because it does not conflict with any aspect of knowledge-about-systems. That is, the components of the model (which will be discussed soon) are elemental to *any* systems concept. Second, one might imagine that such elementalism would also lead to abstraction, and it does. The model provides an abstract framework of scaffolding for knowledge-about-systems. It helps us to organize these myriad systems concepts. In this sense, the model is well-suited to educational settings. In the companion book to a seminal work by the same title, *How People Learn: Bridging Research and Practice,*[191] Donovan summarizes the three main findings of learning and educational research:

> 1. Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they will learn them for purposes of a test but revert to their preconceptions outside the classroom
> 2. To develop competence in an area of inquiry, students must: (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application.

> 3. A “metacognitive” approach to instruction can help students learn to take control of their own learning by defining learning goals and monitoring their progress in achieving them.[191(pp10-13)]

These findings suggest a dual approach to learning and teaching. That is, factual knowledge (e.g., systems science concepts) must be combined with a conceptual organizing framework. In addition, it is critical that teachers be aware (and students be reflective) about their own preconceptions and metacognitive process. They must develop a conceptual understanding of both the structure and dynamics of preconceptions and of new learning. By using patterns of systems thinking, students may understand how their preconceptions are conceptually structured to ignore certain important features the new learning focuses upon. In this way, there is a one-to-one mapping of preconceptions and new learning that cannot be undone. Similarly, the same process can be used by teachers to understand the structure of a student’s preconceptions. Each of these processes are central to bridging the research and practice of learning.

In addition, it is suggested that the processes that occur at one level of thinking (say, inside the mind) between one thought and another are essentially the same set of processes that occur between groups or between organizations or between countries. That is, that the most complex systems of thought imaginable are structurally the same as a single simple concept. The term “fractal” is used to describe this self-similarity across scale. Figure 7.6 shows a fractal structure called the Mandelbrot fractal.[192] “Fractals can be most simply defined as images that can be divided into parts, each of which is similar to the original object.”[193] This means that, like a fractal structure, the same conceptual structures are occurring across conceptual scale—that a single concept and a complex of concepts share the same basic structure and repeating patterns.

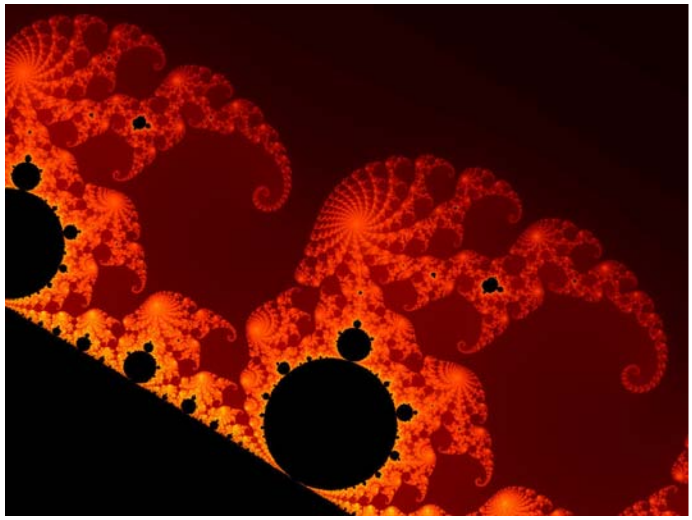


Figure 7.6: A Mandelbrot Fractal Showing Self-Similar Structures Across Scale[192]

The terms “minimal concept theory” are used as an analogy to a theory in bioengineering called “minimal cell theory.” In this theory, scientists are attempting to model a single cell based only on the parts that are absolutely necessary for cell function. A “minimal cell” is a “hypothetical bacterial cell with the minimum number of genes necessary to perform all the essential functions.”[194] Dr. Michael Schuler developed the Cornell minimal cell theory. Browning and Schuler write, “A model of a minimal cell would be a valuable tool in identifying the organizing principles that relate the static sequence information of the genome to the dynamic functioning of the living cell.”[195(p187)]Figure 7.7 shows a sketch of a minimal cell model.

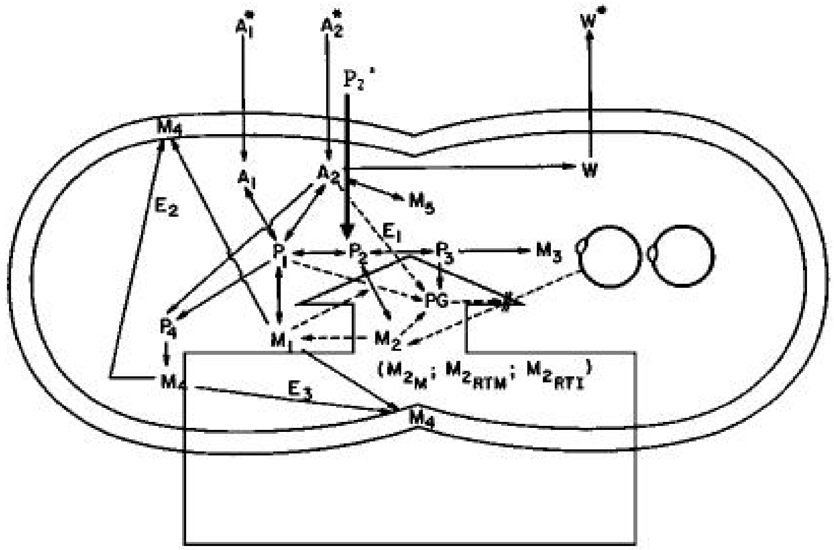


Figure 7.7: A Sketch of Minimal Cell Model[195]

Some of the ways that scientists have progressed in their understanding of the components and interactions of a minimal cell is to use a technique called "knock out analysis" in which they remove or "knock out" one component at a time to see if the cell can function without that component. This is not a foolproof technique, of course, because there may be multiple dependencies, but it is a worthwhile technique that produces knowledge on the topic, and scientists are progressing toward a more complete understanding of the minimal cell.

By way of an analogy to the minimal cell theory, a "minimal concept theory" is proposed in which we attempt to identify the structure and dynamics of a single concept that are absolutely necessary. In this way, it would be possible to identify the basic components of a conceptual system and the underlying rule structure of systems thinking.

An overview of the Minimal Concept Theory of Systems Thinking (Table 7.2) is proposed here with full knowledge that a more complete treatment than can be provided here in the conclusion is necessary.

Table 7.2: Toward the Middle Way Ideal: The Minimal Concept Theory of Systems Thinking

Systems thinking is a conceptual framework, derived from patterns in systems science concepts, theories and methods, in which a concept about a phenomenon evolves by recursively applying rules to each construct and thus changes or eliminates existing constructs or creates new ones until an internally consistent conclusion is reached. The rules are: • **Distinction making**: differentiating between a concept's identity (what it is) and the other (what it is not), between what is internal and what is external to the boundaries of the concept or system of concepts; • **Interrelating**: inter-linking one concept to another by identifying reciprocal (i.e., 2 x 2) causes and effects; • **Organizing Systems**: lumping or splitting concepts into larger wholes or smaller parts; and, • **Perspective taking**: reorienting a system of concepts by determining the focal point from which observation occurs by attributing to a point in the system a view of the other objects in the system (e.g., a *point of view*).

Figure 7.8 illustrates the rule structure of MCT/ST. Most important, it shows that each component of the Theory (i.e., *Distinction-making (D)*, *Organizing Systems (S)*, *Inter-relating (R)*, and *Perspective-taking (P)*) is self-similar to the other components and to the model itself (i.e., it is a *mise en abime* fractal structure). For example, the *Organizing* portion of the pie includes two elements that relate in four ways (a relationship 2 x 2). One of the elements (part) can be thought of as reductionistic, while the other (whole) can be thought of as holistic (i.e., middle way). The two elements together make up the larger whole of the component, *Organizing*

Systems. Similarly, each of the other components is structured the same way (two balanced elements) and shares the same dynamics (i.e., fractal self-similarity). That is, each component is itself a system of interrelated distinctions, one with its own perspective on the larger whole. The elements of each component are parts, while the component itself is a whole. The two elemental parts of each component interrelate in way that is unique to that component. All three, the interrelations, the component and the elements, are distinctions, and these distinctions interact to define each other, and each offers a unique point of view (perspective) on the system as a whole. Because each component is self-similar to the whole Model, no component or element can exist without the other components or elements. This is precisely why the Model reaches an enclosed state and why additional components are not needed (i.e., satisfies knock-out analysis). Occam's Razor states, in Latin, "*Entia non sunt multiplicanda praeter necessitatem*" which in English means, "*No more things should be presumed to exist than are absolutely necessary.*"[196] The algorithm (the DSRP rule set) that underlies the MCT/ST explains why other components are not necessary to create a concept.

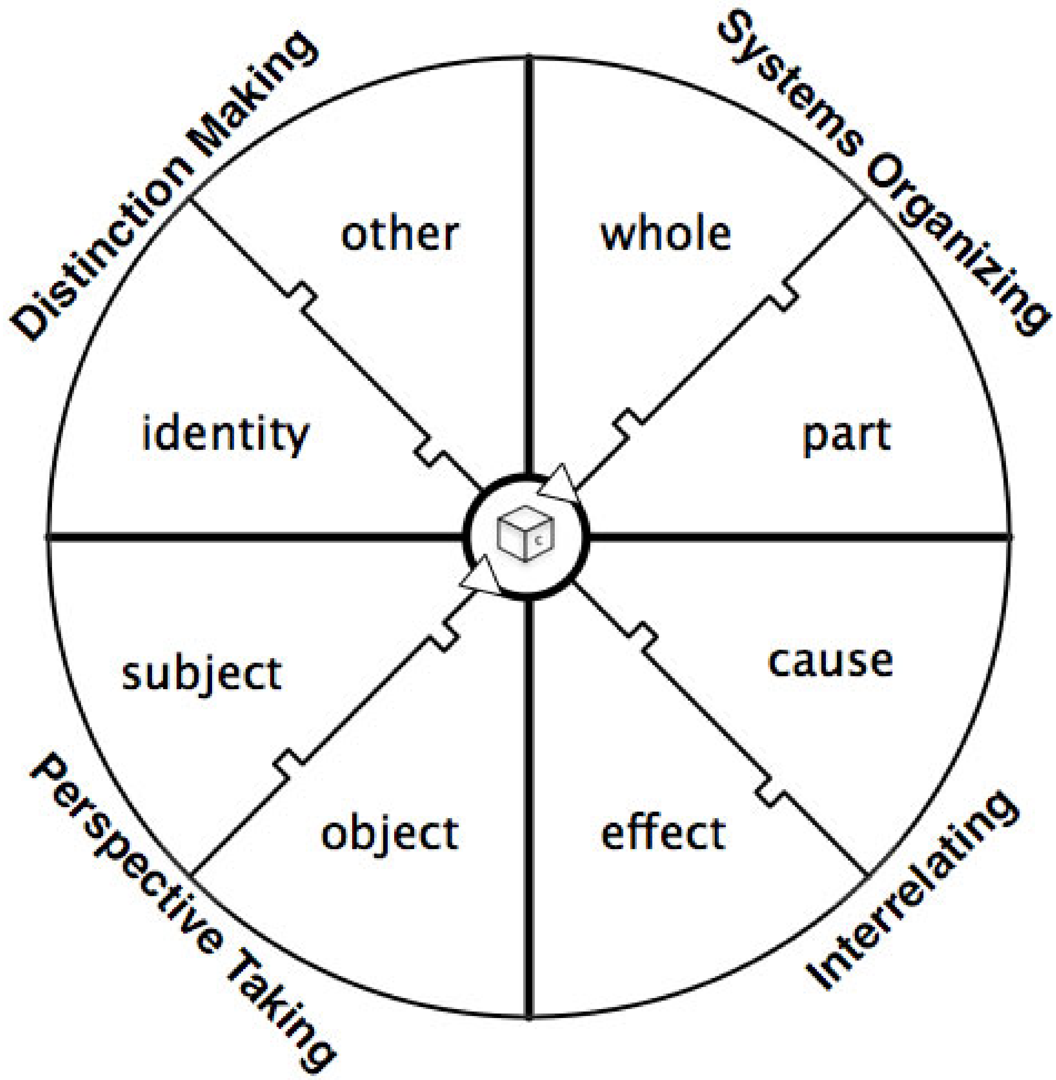


Figure 7.8: A Minimal Concept Theory of Systems Thinking

The dynamics of the Model are simple, yet the result is extremely complex. Table 7.3 illustrates how each component interacts with dynamic complexity. Note that the variables of each component (e.g., identity, other, part, whole, etc) shown in Figure 7.6 also interact in a similar matrix to Table 7.3 (not shown here).

Table 7.3: The Dynamic Complexity of the MCT/ST

	Distinction Making	**Organizing Systems**	**Interrelating**	**Perspective Taking**
Distinction Making	-	A distinction (a whole) is an organization of *identity* parts and *other* parts	A distinction is a relationship between identity and other	Every distinction involves a perspective in order to establish an identity
Organizing Systems	An organization is a distinction between parts and whole and between what is internal and external to the whole	-	Organizing is relating parts to their whole and creating nested relationships with wholes as parts within still larger wholes	Organizations contain numerous perspectives including the whole itself and each of its parts
Interrelating	A relationship is a distinction between the causes of one object and the effects on another.	A relationship (a whole) is an organization of cause parts and effect parts	-	A relationship is made up of a quadratic set of perspectives based on bidirectional cause and effect (feedback)
Perspective Taking	A perspective is a distinction between the view of a subject (identity) and the objects viewed (other)	A perspective (a whole) is an organization of subject view (part) and viewed object (part)	A perspective is a relationship between a subject view and an viewed object	-

It is widely accepted that all thought is born of *distinction making*. Distinction making is identical to a boundary critique as both processes cause one to demarcate between what is in and what is out of a particular construct. Boundary critique may also allude to how one must be explicit (e.g., critical) of these boundary decisions. Distinction making, on the other hand, is autonomic—one constantly makes distinctions all of the time. Whether one is critically reflective of the boundaries one draws when making distinctions is secondary to the fact that one is always making distinctions. Systems thinking, then, is looking systemically at how these distinctions are made, informed by the counterclaims discussed in Chapter 3; that is, informed by a process that is reductionist and holist, conceptual, cognizant of relational and structural parts, and characteristic of the patterns of thinking that inform knowledge-about-systems. MCT/ST is aligned with each of these counterclaims. Figure 7.8 and Table 7.3 show how the Model works to make distinctions in a way that is both discrete and proximal.

All thinking is distinction making. But distinctions are more complex than one might initially expect. This complexity, however, is based on simple rules that determine how a distinction is made. Because all distinctions are created based on these rules, they can be compared and contrasted, summarized and integrated according to these rules.

Figure 7.9 illustrates some of the complexity involved when a distinction is made. For the purpose of explanation, one can assumea finite and static universe of concepts represented by the linear network of grey nodes. Each node represents a concept. For the purpose of explanation one can assume these concepts cannot be further reduced, although it is obvious that they could be. That is, they are not systems of concepts but are merely singularities or chunks that cannot be broken down any further, and no additional concepts can be added.

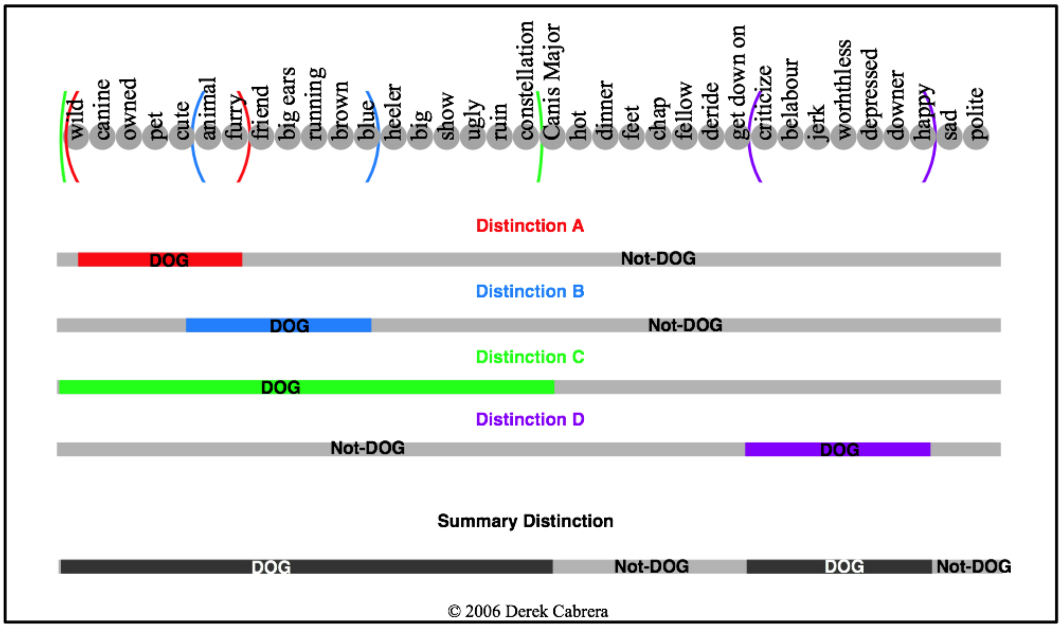


Figure 7.9: Discrete and Proximal Distinction Making

Now, suppose that there are four people, and each of them, upon seeing the finite universe of concepts, makes a single distinction. This would be akin to seeing a large grouping of pixels and seeing a face or a vase or some other distinctive feature. The first person (red ellipse/bar) makes distinction A; the second person (blue ellipse/bar) makes distinction B; the third person (green ellipse/bar) makes distinction C; and the fourth person (purple ellipse/bar) makes distinction D. Each of the participants gives his or her conceptual distinction a name. The only problem is that each person gives his or her distinction the *same* name: DOG. In other words, four people have used the same term to represent very different conceptual systems.

Figure 7.9 illustrates how each of four people uses a finite universe of base concepts to make a distinction. It so happens that the distinction they make is given the same name, but it is clear that the content of each distinction differs dramatically because each distinction includes different concepts (nodes). Each distinction is a system of concepts and relationships organized in a particular way. Thus, the nodes inside the red parentheses are how one person defines DOG, while the nodes inside the blue, green, and purple parentheses are how the other three people define DOG.

The bars beneath (Figure 7.9) illustrate that each person's distinction of DOG is composed of both what the person perceives is included in DOG and what the person perceives is not included in DOG. That is, a distinction is a boundary. A distinction is not, as we often are prone to misunderstand, the object itself but is instead a boundary between the object and what it is not. These two states are called *identity* and *other*. One could alternatively think of these states as thing and not-thing, here and there, this and that, us and them, in and out, internalities and externalities. Although the terms "identity" and "other" are used here, of importance is that what all of these contrasted distinctions have in common is that they are relative. In other words, one could view them from two directions. Consider for a moment that we make the distinction *us* and *them*. It is easy to see that from the perspective of those whom we call "them," "us" is a group that they would call "them." Therefore, conceptually, when we take perspective, we are oscillating between a scenario in which we are in one moment *us* and in the next moment *them*. The distinction is relative because we are attributing a state of mind to *them,* and in seeing the world from their perspective, we see a group of people (a group that we actually belong to) called "them." This is the interaction between distinction-making and perspective-taking. One conceptual activity could not occur without the other; therefore, both are necessary in a thinking model of any kind. The fact that explicit distinction making and perspective taking causes one to be critically reflective about the boundaries one makes and how different boundaries will be perceived differently by different perspectives is, at its core, systems thinking.

It turns out, however, that in order to make just a single distinction, distinction making and perspective taking are not enough. Two other functions are *required*; that is, not a single concept could be made (not even one!) without these functions. In order to make even a single concept, four functions are required. The first two we have discussed (Distinctions and Perspectives). The remaining two are Interrelating and Organizing.

Notice that each distinction is actually a collection of smaller distinctions. This collection of smaller distinctions is *organized* in some way based on containment (parts inside wholes that are, in turn, parts of larger wholes). Even in its most abstract state, a distinction is made of some conceptual object that is identity and another conceptual object that is other. Of course, the distinction is the inter-relationship between this identity and other. This relationship, the perspective, the different parts (including the relationship), and the organization of those parts into a whole (such as DOG or any other concept) is a complex process based on very simple rules.

Each person's distinction then, is made up of both what he or she considers is internal to the construct, DOG, and what he or she considers is external to it. Note that there is some agreement and some disagreement about this. The lowest bar in Figure 7.9 illustrates a simple summary distinction of the four distinctions; a more complex analysis based on a proximal distinction is yielded by MDS analysis on the distinction making of each perspective (see Table 7.4).

Table 7.4: The Summary Table for the Distinction DOG

Content ID	Content	PersonA	PersonB	PersonC	PersonD
node1	wild	1	0	1	0
node2	canine	1	0	1	0
node3	owned	1	0	1	0
node4	pet	1	0	1	0
node5	cute	1	1	1	0
node6	animal	1	1	1	0
node7	furry	0	1	1	0
node8	friend	0	1	1	0
node9	big ears	0	1	1	0
node10	running	0	1	1	0
node11	brown	0	1	1	0
node12	blue	0	0	1	0
node13	heeler	0	0	1	0
node14	big	0	0	1	0
node15	show	0	0	1	0
node16	ugly	0	0	1	0
node17	ruin	0	0	1	0
node18	constellation	0	0	0	0
node19	Canis Major	0	0	0	0
node20	hot	0	0	0	0
node21	dinner	0	0	0	0
node22	feet	0	0	0	0
node23	chap	0	0	0	0
node24	fellow	0	0	0	0
node25	deride	0	0	0	0
node26	get down on	0	0	0	1
node27	criticize	0	0	0	1
node28	belabour	0	0	0	1
node29	jerk	0	0	0	1
node30	worhthless	0	0	0	1
node31	depressed	0	0	0	1
node32	downer	0	0	0	1
node33	happy	0	0	0	0
node34	sad	0	0	0	0
node35	polite	0	0	0	0

In Table 7.3, a 1 was entered if the person included the node-concept, and a 0 was recorded if the person did not include it. Table 7.3 shows four distinctions. Figure 7.10 shows a graph of the positive (identity) values for the four combined distinctions. Ror example, one can see that node5 (cute) and node6 (animal) are most often included as parts of the DOG construct in our hypothetical world. Figure 7.11 shows the same data input into an MDS analysis to produce a concept map.

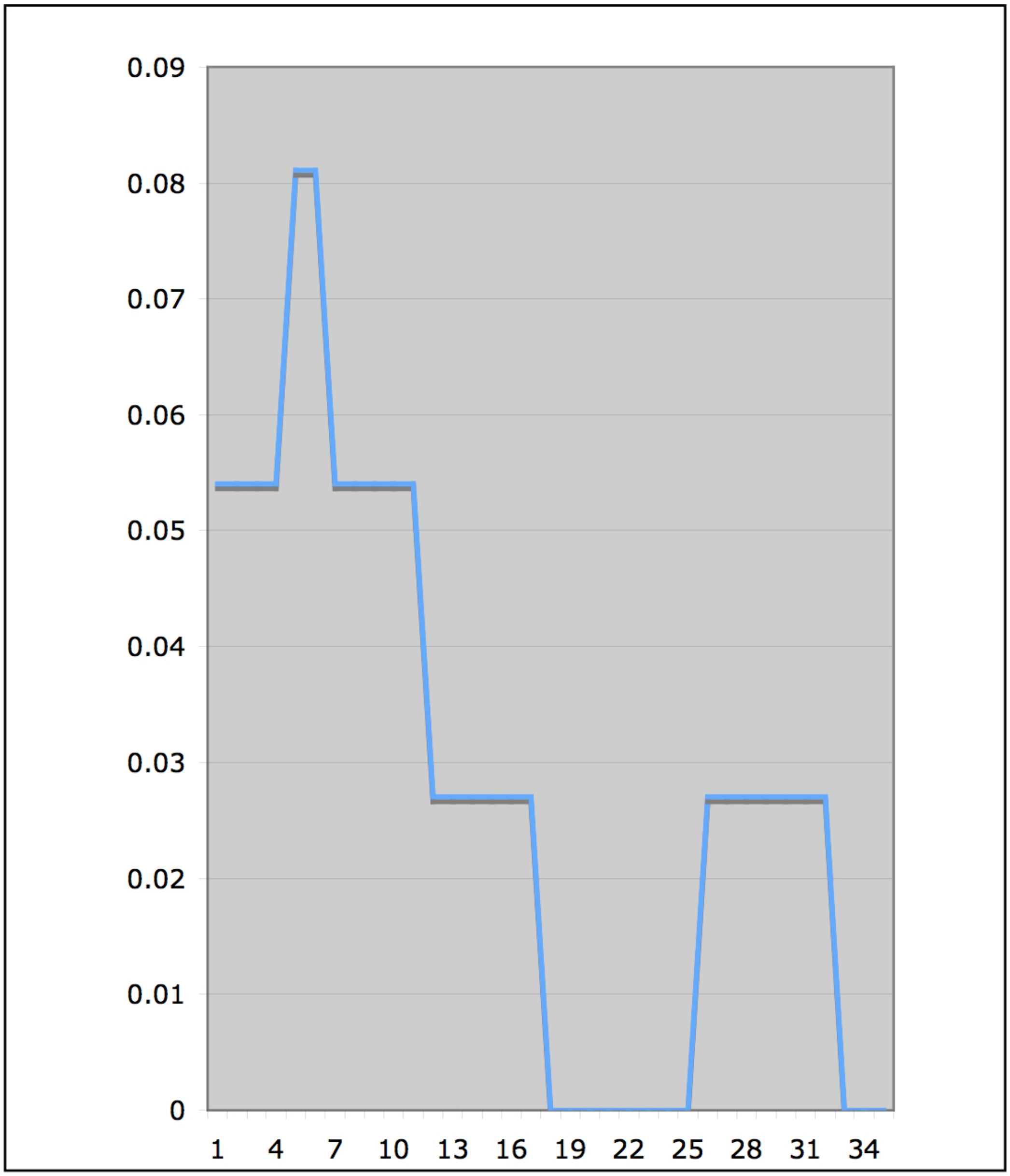


Figure 7.10: Graph of Positive (Identity) Values Dog Distinction for Four Perspectives

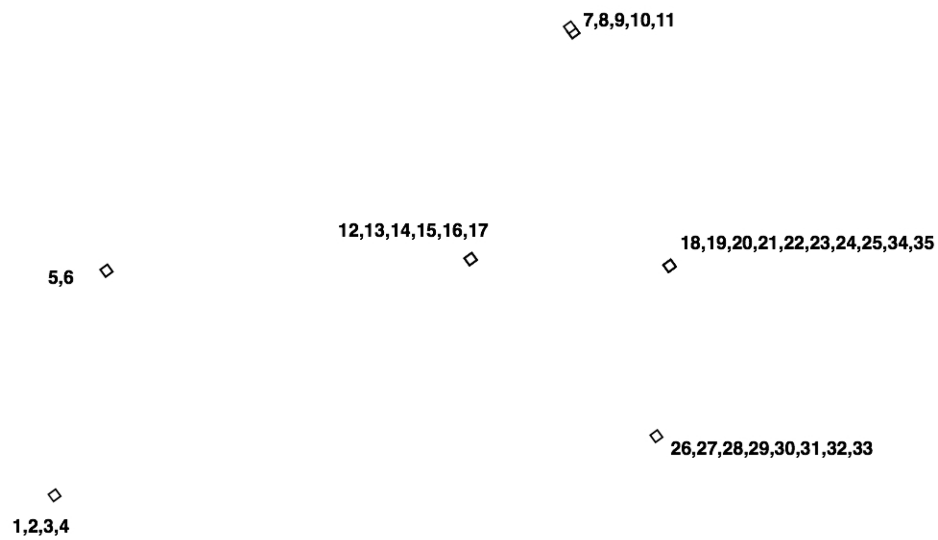


Figure 7.11: Multidimensional Scaling Analysis of “Dog Concept” from Four Perspectives

Note that the individual nodal-concepts are stacked into six piles. This is because the sorting from Table 7.4 is binary (each person has only two sort piles). Each of these piles corresponds to obvious line segments in the graph in Figure 7.10. However, the MDS configuration of these data is very different. First, this MDS map is non-metric. This means that the absolute position of each numbered item is meaningless. What is meaningful is the relative position of each item to the other items. We already know that there are 35 discrete concepts in this map. We also know that these are merely parts in a more complicated distinction process involving four different perspectives (people, in this case). But what is really going on is much more complex, even though it is based on simple rules.

Figure 7.12 illustrates the MDS analysis of the four perspectives on the DOG construct. Overlaid onto the map is the dynamics of the Middleway model. The DOG concept is anchored at points 5 and 6. The NOT-DOG concept is anchored at overlapping points 18, 19, 20, 21, 22, 23, 24, 25, 34, and 35. These are the points that the four persons included in their definitions of DOG and, conversely, NOT-DOG. Note that the perspective-taking rule is the mechanism that causes DOG and NOT-DOG to oscillate between the coupled identity and other states. These states are "coupled" because when one state switches, the other state will switch to its opposite state. The distinction-making rule accounts for these two states only (identity and other), but it is the perspective-taking rule that acts upon these states to entirely transform the distinctions, inter-relationships, and organization of the construct by selecting the identity-state and determining the point of view. So, using binary numbers, DOG and NOT-DOG can be in either "On" or "Off" positions (1,0). Because they are both concepts themselves (one can actually think about the concept NOT-DOG), one can attribute a perspective to either concept. Therefore, if NOT-DOG is "on" (1), then DOG is "off" (0). This means that the collections of things that are part of DOG are actually, for this brief moment, a collection of things that are part of NOT-NOT-DOG. NOT-NOT-DOG (a.k.a., "DOG") is the "other-state" to the identity of NOT-DOG. This may sound complicated, but it is really no different from the us/them oscillation. A double negative is a positive, so that DOG is the same as NOT-NOT-DOG.

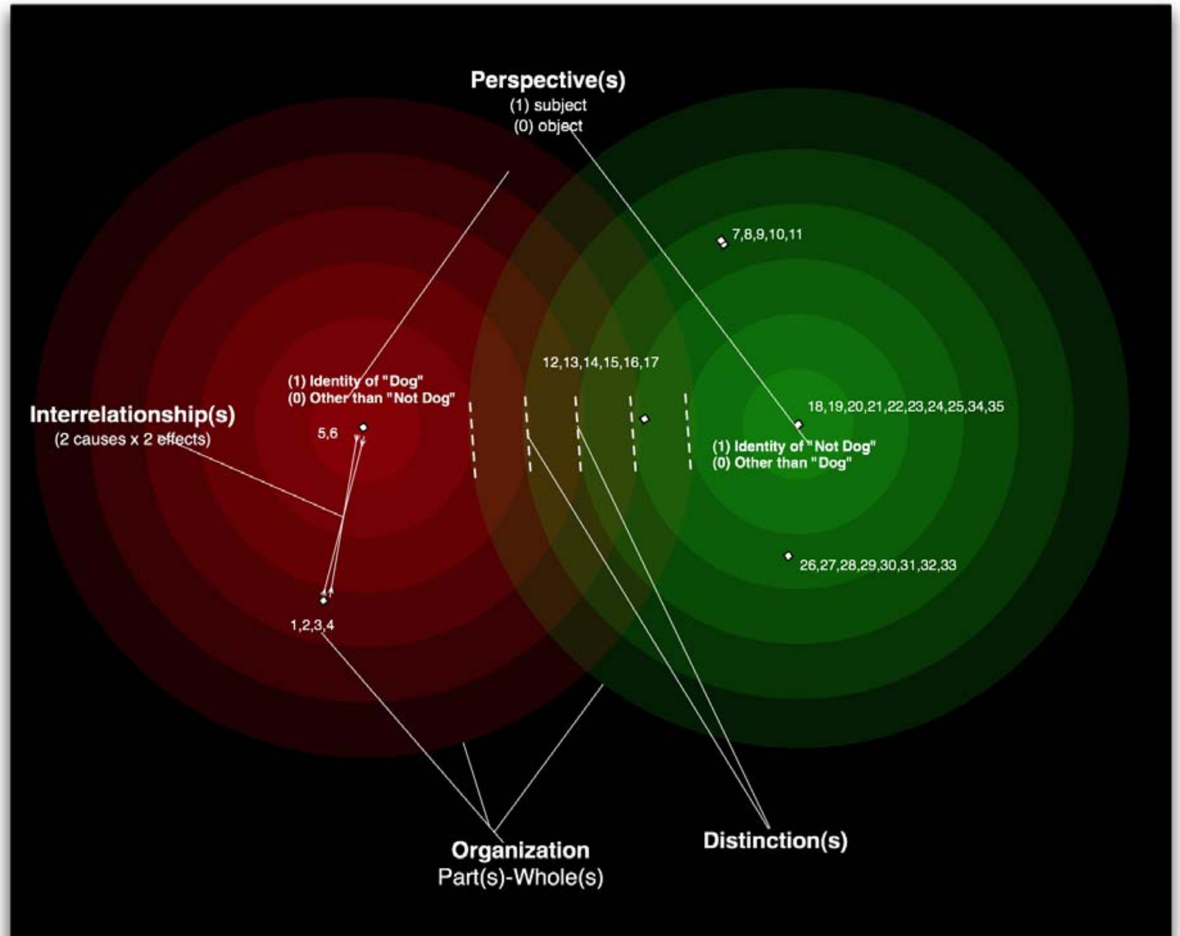


Figure 7.12: MDS Analysis of "Dog Concept" from Four Perspectives Detailing the Dynamics of the MCT/ST

The concentric circles in Figure 7.12 radiate from the two coupled anchor points that are in alternative states, identity and other. The concentric radiation represents distance away from the anchor. In a sense, the farther one moves from the 5,6 anchor points, the farther one moves from DOG (or, alternatively, NOT-NOT-DOG). Playing with boundary critique, when one draws a boundary at the third concentric circle, one makes a distinction (dotted line) at the interface of the two radiating concentric circles. What is most important, however, is that if one could freeze for an instant in that distinction making act, one would see a great number of moving parts come to a halt.

For example, perspective would collapse onto DOG as the identity-state, which would in turn place NOT-DOG into the other-state. At the same instant that the distinction is drawn at the fourth concentric circle, an interface is occurring between a host of relationships between different parts (all of the numbered concepts in the alternative four concentric circles). Each of these relationships alternatively is a distinction (so it can become tremendously complex). All of this, the perspectives, the relationships, the distinctions, is organized into a whole composed of all of these moving parts that have not been frozen in time. The net-result is the concept DOG.

The important conclusion is that all distinctions are based on other distinctions. Furthermore, every distinction requires the four functions described above. In turn, each of these four functions (combined with content such as DOG) spins off new distinctions. Thought is infinite, endless, and ongoing. Because systems are essentially entities of some kind, and because the Middleway model is really nothing more than a theory of how entities interact, developing one's ability to think in systems is no more complicated than understanding how entities fundamentally interact. When two entities come together and relate in some way, there are at least two perspectives, which means that the entire organization of reality can be configured in at least two distinct ways. This may sound constructivist or even relativist. It is, in one sense. But, as has been shown, the combination of multiple perspectives—whether they be four thoughts, four people, four groups, or four countries—can be shown to have both proximal and discrete outputs. In another sense, therefore, there is reality beyond the relativity. It has also been shown that the whole (even in something as abstract and complex as a concept) cannot possibly be more than the sum of its parts. It is sometimes difficult to understand or capture all of the parts because there are so many of them, even in relatively simple systems, but there is no need for metaphysical metaphors of emergence.

It is not feasible to provide a complete treatment of the MST/ST herein. Such a treatment would require at least an additional book's length. Thus, this section serves as an appetizer of sorts for future theoretical and empirical work in systems thinking.

Ecosphere: A Model System

The progression above is a "slightly" more abstract description of the MST/ST. However, these are meaningful abstractions that help us to think about real systems. It may assist the reader to consider a more tangible example based on something one can hold in one's hand but which also maintains most of the complexities of real-world systems. In the example, key words that have to do with the proposed systems thinking model are underlined.

All systems thinking is "closed" systems thinking. That is, all thinking involves a boundary of some kind. This boundary is often arbitrary or based on the particular needs of the systems thinker. One good example of a tangible closed system is the ecosphere. Drs. Joe Hanson and Clair Folsome first developed the "ecosphere"—a self-contained miniature biological world—and NASA became interested in these closed self-sustaining systems under their Mission to Discover Planet Earth program. Today, small ecospheres are sold for $100 to $500 for educational purposes or as home décor. Commercial ecospheres, such as those sold by Ecosphere, Inc., include a number of inter-related parts. A glass-blown bulb provides enclosure for the system. Therefore, the system itself is a distinction that has an identity (ecosphere) and interacts with things other than it. Although we call an ecosphere a closed system, it relies on three external phenomena. First, it must receive sunlight (energy). Second, it must be kept at a reasonable temperature for sustaining the life balance within it. Third, it must have a reasonably stable environment (e.g., a stationary table or a shelf). That is, an ecosphere perpetually mounted on the hindquarters of a racehorse will eventually not sustain itself.

Inside the ecosphere the parts include brine shrimp, a branch-like twig, gravel, snail shells, algae, and water. Each of these things is a distinction but also a part in the larger whole. Of course, each of these things is a whole, too, made up of lesser parts that are not all visible to the naked eye. For example, the brine shrimp is made up of a tail, head, eyes, and internal organs. Each of these parts is a distinction and each of these is a whole system, an organization of many inter-related parts. The ecological system we call an ecosphere has ecological analogs in the tiny intestine of the brine shrimp, for example. Each of these systems is built upon inter-relationships between parts of the whole. The system itself, including all of these parts and inter-relationships, is exactly equal to the sum of these parts and relationships. The difficulty is knowing whether one has accounted for them all. We think of most of the relationships as invisible. But this is not necessarily the case. The brine shrimp, for example, can be thought of as a relationship between the algae and shrimp feces in the same way that a combustible engine is a relationship between gasoline and exhaust. The brine shrimp is the relationship between these two parts of the whole ecosphere. The feces inter-relates to the microorganisms and bacteria that break down the shrimp's waste into inorganic nutrients and carbon dioxide that are again used by the algae that in turn provide sustenance for the shrimp. Like each of these individual relationships—complex in and of themselves—the brine shrimp is merely a collection of lesser parts—an organization of inter-relations. These lesser parts are merely organizations of inter-relations. At each level of scale (perspective), one can "zoom in" and see inter-relationships and organization.

There are also many distinctions we don't "see" or that we have decided not to recognize. For example, an important functional part of the ecosphere is the *atmosphere* that exists directly above the water. The water and the atmosphere are made up of gasses and molecules, each of which is a distinct part in a larger, organized and interrelated whole. The gravel, twig, and glass provide important "surface area[s]" that "act as hiding places where microorganisms and algae can attach themselves."[197]

The distinctions we make are not absolute. That is, like the DOG distinction, they are each proximal in nature. For example, what the untrained eye might call a "twig" is actually a corral called *gorgonia*. From the perspective of a biologist who studies *gorgonia,* there would likely be many more complex and refined distinctions he or she would consider. Likewise, a physicist's perspective, as Feynman explained, might see the glass globe as a "distillation of the Earth's rocks," and he or she might see the gravel as mineral deposits assisting in the delicate balance of the ecosphere. Each of these is an organized distinction comprising other inter-related distinctions, and each of these organized systems of distinctions is changes dynamically according to where the emphasis is placed by virtue of the perspective. Metaphors, similes, and analogies are also types of perspectives that transform the organization of inter-relationships and distinctions of the whole system. For example, ecospheres are sometimes thought of as "biological batteries" because they store light energy that was converted from biochemical processes.

Not all perspectives are from outside the system looking in. Not all perspectives are from actual people. Remember that each distinction involves a perspective. In addition, each distinction can be attributed a unique perspective. Therefore, we might conceptualize the ecosphere from the point of view of the brine shrimp or the algae. Furthermore, we may not want to anthropomorphize these perspectives when we attribute them. That is, we may want to view the system as the shrimp "views" it, with all the sundry mental and sensory faculties of a brine shrimp; these may include actually seeing or sensing things that we do not, like tiny microorganisms that exist throughout the ecosphere and are critical in its functional balance. Or we may wish to make an anthropomorphic analogy between the shrimp and the human participants who lived in an actual, human-scale ecosphere in Arizona called Biosphere 2, or even those of us who are living, right now, in another ecosphere called Biosphere 1 (a.k.a. the Earth).

There are also numerous other perspectives, all of which transform the organization of inter-relations and distinctions. For example, as in Biosphere 2 (and many hope someday for Biosphere 1), the tiny pink occupants of the ecosphere were "chosen because they do not show aggression toward each other."[197]

At each step along the way, we are making choices about what to re-cognize, about what to include and exclude, and from which perspective we view the system. There are various distinctions, inter-relationships, organizations of parts and wholes, and perspectives; some of these are visible to the naked eye and some invisible. But there are many more invisible to the "mind's eye," limited by our knowledge of the shrimp, or the algae, or the glass, or the system itself. On the other hand, we may purposefully limit ourselves, knowing that taking into account the sun's energy (a constant) in order to plan our next management meeting is unnecessary. We draw these boundaries constantly, many more times than we are aware.

Systems thinking is the process of becoming more aware of these processes—processes we are already experiencing all of the time. What we so rarely do, however, is to think critically and reflectively about how we form the distinctions we make or from which perspective these distinctions are made, or which relationships we have ignored because they are invisible either to our naked eye or to our mind's eye.

Pluralism of the MCT/ST

Why, then, is it suggested that the MCT/ST is more pluralistic than other models of systems thinking such as system dynamics? It is because the components of the model are abstract in nature. That is, the model tells us that there are inter-relationships and it tells us how they will always work at a fundamental level, but it does not tell us what types of relationships exist in the particular system of interest. This is appropriate because there are many types of relationships: linear ones, nonlinear ones, simple and complex ones, feedback relationships of various kinds (vicious, virtuous, and balancing, for example), or structural ones such as the shrimp itself as an organization of lesser parts. Similarly, the organizing rule tells us that all wholes have parts and that all parts are themselves wholes, and vice versa. The organizing rule does not tell us what type of organization exists in the particular system of interest. As with inter-relationships, there are numerous types of organization (hierarchical, heterachical, flat, complex, simple, human, biological, mechanistic, etc.), but all of these types work on this fundamental rule structure. The types of relationships, distinctions, organization, and perspective one decides to emphasize (re-cognize) depends on the particular system of interest and the situation one is attempting to think about. The systems thinking models that exist today are predicated on certain types of systems of interest such as systems that are best described as organic (GST), or those best characterized by feedback and stocks and flows (system dynamics), or by stakeholders (various social systems models).

While the MCT/ST is linked to basic physical systems because it deals with abstract entities of any kind, it is intended to be a conceptual system. That is, it describes how conceptual systems work, rather than "real" systems *per se*. Because the Model is based on the fundamental interactions between and the organization of any set of abstract entities, it can be applied to any physical, biological, or social system. At its core, however, it deals with conceptualization.

Conclusion

In September 2005 a small team of doctoral students at Cornell University convened a weekly meeting with the intention of developing curriculum for a senior capstone course for students at Cornell. The idea for the course was simple: the course would be for departing seniors, taken during their last semester, and would be the motivational equivalent of a commencement address that lasted 16 weeks. The team hoped that the content of the course, delivered by a host of inspirational faculty speakers, would frame "the crisis facing the planet" and motivate students to venture into the world with both a vision and a cause.

Perhaps the "What is the Crisis? Course" should be offered to students in the fall of their senior year. Faced with the many complex problems that face humanity, students will want to think beyond these problems to possible solutions. As they do, the onus is on us—as systems thinkers and educators—to guide them toward the conceptual tools they will need to solve these problems. Furthermore, systems thinking is not just for the undergraduate classroom. It is increasingly being recognized as a critically important construct in many disciplines and practical arenas. Yet it is a construct that is confused, ambiguous, and surrounded by misinformation. There are many practical challenges to implementing systems thinking, not the least of which is this construct ambiguity. Even so, through learning from implementational efforts and through staging appropriate research, we can grope toward an evolved understanding of systems thinking. At the same time, we need to make progress in theory development related to systems thinking. If systems thinking is, as is suggested here, a collection of thinking patterns, then we may be able to describe these general patterns and develop a clear understanding of their structure and process. A tentative theory of systems thinking, called DSRP, is offered here as a starting point. In the future, further development of this theory is needed. A combination of approaches is suggested for this future work. More empirical and theoretical work is needed, but also more experiential and practical work. In addition, much educational work is required. In combination, these efforts, although blindly variant in many ways, will eventually settle upon and select for a more optimal systems thinking construct.

APPENDIX 4A: Methods Analysis of Systems Thinking in Public Health Publications

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	SA	ST	E	Surveys and interviews	All health officers and health department executives in California	Lammers, J. C. and V. Pandita	1997	Applying systems thinking to public health leadership.	Journal of Public Health Management & Practice 3(4): 39-49.
PH	SA	ST	E	Quasi-experimental design, surveys, and qualitative analysis	7 sites in New York State the offer mental health services	Huz, S., Andersen, D. F., Richardson, G. P., & Boothroyd, R.	1997	A framework for evaluating systems thinking interventions: An experimental approach to mental health system change.	System Dynamics Review
PH	SA	ST	T/TP/O	n/a	n/a	Chan, C.-P. C. A.	2001	Implications of organizational learning for nursing managers from the cultural, interpersonal and systems thinking perspectives.	Nursing Inquiry 8(3): 196-199.
PH	SA	ST	T/TP/O	n/a	n/a	Green, L. W.	2006	Public Health Asks of Systems Science: To Advance Our Evidence-Based Practice, Can You Help Us Get More Practice-Based Evidence?	American Journal of Public Health 96(3): 1-4* (page numbers not finalized).
PH	SA	ST	T/TP/O	n/a	n/a	Homer, J. B. and G. B. Hirsch	2006	System Dynamics Modeling for Public Health: Background and Opportunities.	American Journal of Public Health 96(3): 19-25 (page numbers (page numbers not finalized)).

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	SA	ST	T/TP/O			Rodrigues, B.	2002	Health Care Reform: Opportunities for Professional Chaplains to Build Intentional Communities of Learners by Integrating Faith, Science, Quality, and Systems Thinking.	Journal of Health Care Chaplaincy 13(1): 195-211.
PH	SA	ST	T/TP/O			Rothschild, A. S., L. Dietrich, et al.	2005	Leveraging systems thinking to design patient-centered clinical documentation systems.	International Journal Of Medical Informatics 74(5): 395-398.
PH	SA	ST	T/TP/O	n/a	n/a	Lindberg, C., Herzog, A., Merry, M., & Goldstein, J.	1998	Life at the edge of chaos - health care applications of complexity science.	The Physician Executive (January-February), 6-20.
PH	SA	ST	T/TP/O	n/a	n/a	McDaniel, R., & Driebe, D. J.	2001	Complexity science and health care management.	In J. Blair, M. Fottler & G. Savage (Eds.), Advances in health care management (Vol. 2, pp. 11-36): Elsevier Science Ltd.
PH	SA	ST	T/TP/O	n/a	n/a	Midgley, G.	2006	Systemic Intervention for Public Health.	American Journal of Public Health 96(3): 33-39 (page numbers (page numbers not finalized)).
PH	SA	ST	T/TP/O	n/a	n/a	Plsek, P. E. and T. Wilson	2001	Complexity science - Complexity, leadership, and management in healthcare organisations.	British Medical Journal 323(7315): 746-749.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	SA	ST	T/TP/O	n/a	n/a	Plsek, P. E., & Greenhalgh, T.	2001	Complexity science - the challenge of complexity in health care.	British Medical Journal, 323(7313), 625-628.
PH	SA	ST	T/TP/O	n/a	n/a	Pruessner, H. T., W. A. Hensel, et al.	1992	The Scientific Basis Of Generalist Medicine.	Academic Medicine 67(4): 232-235.
PH	SA	ST	T/TP/O	n/a	n/a	Holden, L. M.	2005	Complex adaptive systems: concept analysis.	Journal Of Advanced Nursing 52(6): 651-657.
PH	SA	ST	T/TP/O	n/a	n/a	Leischow, S. J. and B. Milstein	2006	Systems Thinking and Modeling for Public Health Practice.	American Journal of Public Health 94(6): 403-405 (page numbers (page numbers not finalized)).
PH	SA	ST	T/TP/O	n/a	n/a	McCubbin, M. and D. Cohen	1999	A systemic and value-based approach to strategic reform of the mental health system.	Health Care Analysis 7(1): 57-77.
PH	SA	ST	T/TP/O	n/a	n/a	Paton, K., S. Sengupta, et al.	2005	Settings, systems and organization development: The healthy living and working model.	Health Promotion International 20(1): 81-89.
PH	SA	ST	T/TP/O	n/a	n/a	Suchman, A.	2002	Linearity, complexity and well-being.	Medical Encounter, 16(4), 17-19.
PH	SA	ST	T/TP/O	n/a	n/a	Introcaso, D. M.	2005	The Value of Social Network Analysis in Health Care Delivery.	New Directions for Evaluation 107: 95-98.
PH	SA	ST	T/TP/O	n/a	n/a	Institute of Medicine.	2001	Crossing the quality chasm: A new health system for the 21st	Washington, DC: National Academy Press.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
								century.	
PH	SA	ST	T/TP/O	n/a	n/a	Milstein, B. and J. B. Homer	2005	Background on system dynamics simulation modeling: With a summary of major public health studies.	Washington, DC, Centers for Disease Control and Prevention, Syndemics Prevention Network.
PH	SA	ST	T/TP/O	n/a	n/a	National Cancer Institute.; Cabrera, Trochim	(in preparation)	Greater than the sum: Systems thinking in tobacco control.	Bethesda, MD: U.S. Department of Health and Human Services, National Institutes of Health.
PH	SA	S	E	Surveys and interviews	85 patients with back injuries	Gustafson, D. H., C. P. Helstad, et al.	1995	The Total Costs Of Illness - A Metric For Health-Care Reform.	Hospital & Health Services Administration 40(1): 154-171.
PH	SA	S	E	Soft systems methodology	n/a	Fahey, D. K., E. R. Carson, et al.	2004	Applying systems modelling to public health.	Systems Research And Behavioral Science 21(6): 635-649.
PH	SA	S	E	Soft systems methodology	n/a	Gregory, W. J. and G. Midgley	2000	Planning for disaster: developing a multi-agency counselling service.	Journal Of The Operational Research Society 51(3): 278-290.
PH	SA	S	E	Soft systems methodology	n/a	Luckett, S. and K. Grossenbacher	2003	A critical systems intervention to improve the implementation of a district health system in KwaZulu-Natal.	Systems Research And Behavioral Science 20(2): 147-162.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	SA	S	E	Qualitative analysis; case studies	A non-profit managed care organization in the Midwest	Pronk, N. P. and J. Boucher	1999	Systems approach to childhood and adolescent obesity prevention and treatment in a managed care organization.	International Journal Of Obesity 23: S38-S42.
PH	SA	S	E	Qualitative analysis of workshops	Approx. 600 members of two county health departments in Ohio	Holtzhauer, F. J., J. C. Nelson, et al.	2001	Improving Performance at the Local Level: Implementing a Public Health Learning Workforce Intervention.	Journal of Public Health Management & Practice 7(4): 96-104.
PH	SA	S	E	Qualitative analysis	34 neonatal intensive care units and focus groups of staff from those	Horbar, J. D., P. E. Plsek, et al.	2003	NIC/Q 2000: Establishing habits for improvement in neonatal intensive care units.	Pediatrics 111(4).
PH	SA	S	E	Interviews; Qualitative analysis	Various stakeholders from 34 agencies	Midgley, G. and A. Milne	1995	Creating Employment Opportunities For People With Mental-Health Problems - A Feasibility Study For New Initiatives.	Journal Of The Operational Research Society 46(1): 35-42.
PH	SA	S	M	n/a	n/a	Jones, A. P., J. B. Homer, et al.	2006	Understanding Diabetes Population Dynamics Through Simulation Modeling and Experimentation.	American Journal of Public Health 96(3): 55-61 (page numbers (page numbers not finalized)).

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	SA	S	M	n/a	n/a	Ritchie-Dunham, J. L. and J. F. M. Galvan	1999	Evaluating epidemic intervention policies with systems thinking: A case study of dengue fever in Mexico.	System Dynamics Review 15(2): 119-138.
PH	SA	S	T/TP/O	n/a		Zylinski, J., G. L. Allan, et al.	1998	The implementation of an integrated on-line health education system at RMIT.	International Journal Of Medical Informatics 50(1-3): 261-265.
PH	SA	S	T/TP/O	n/a	n/a	Williams, W., Lyalin, D., & Wingo, P. A.	2005	Systems thinking: What business modeling can do for public health.	Journal of Public Health Management Practice
PH	SA	S	T/TP/O	n/a	n/a	Benko, S. S. and A. Sarvimaki	2000	Evaluation of patient-focused health care from a systems perspective.	Systems Research And Behavioral Science 17(6): 513-525.
PH	SA	S	T/TP/O	n/a	n/a	Best, A., G. Moor, et al.	2003	Health promotion dissemination and systems thinking: Towards an integrative model.	American Journal Of Health Behavior 27: S206-S216.
PH	SA	S	T/TP/O	n/a	n/a	Burke, J. P. and S. L. Pestotnik	1999	Antibiotic resistance-systems thinking, chaos and complexity theory.	Current Opinion in Infectious Diseases 12(4): 317-319.
PH	SA	S	T/TP/O	n/a	n/a	Lenaway, D., P. Halverson, et al.	2006	Public Health Systems Research: Setting a National Agenda.	American Journal of Public Health 96(3): (page numbers (page numbers not finalized)).
PH	SA	S	T/TP/O	n/a	n/a	Seely, A. J. E., & Christou, N. V.	2000	Multiple organ dysfunction syndrome: Exploring the paradigm of complex nonlinear	Critical Care Medicine, 28(7), 2193-2200.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
								systems.	
PH	SA	S	T/TP/O	n/a	n/a	Pukk, K. and D. C. Aron	2005	The DNA damage response and patient safety: engaging our molecular biology-oriented colleagues.	International Journal For Quality In Health Care 17(4): 363-367.
PH	SA	S	T/TP/O	n/a	n/a	Best, A., D. Stokols, et al.	2003	An integrative framework for community partnering to translate theory into effective health promotion strategy.	American Journal Of Health Promotion 18(2): 168-176.
PH	SA	S	T/TP/O	n/a	n/a	Foote, J. L., D. J. Houston, et al.	2002	Betwixt and between: Ritual and the management of an ultrasound waiting list.	Health Care Analysis 10(4): 357-377.
PH	SA	S	T/TP/O	n/a	n/a	Globerman, J.	1999	Hospital restructuring: Positioning social work to manage change.	Social Work In Health Care 28(4): 13-30.
PH	SA	S	T/TP/O	n/a	n/a	Kelley, M. A. and J. M. Tucci	2001	Bridging the quality chasm.	British Medical Journal 323(7304): 61-62.
PH	SA	S	T/TP/O	n/a	n/a	Kennedy, V. C. and F. I. Moore	2001	A Systems Approach to Public Health Workforce Development.	Journal of Public Health Management & Practice 7(4): 17-22.
PH	SA	S	T/TP/O	n/a	n/a	Kitson, A.	2002	Recognising relationships: reflections on evidence-based practice.	Nursing Inquiry 9(3): 179-186.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	SA	S	T/TP/O	n/a	n/a	Lenihan, P.	2005	The public health system: An idea whose time has come.	Journal of Public Health Management & Practice 11(2): 165-167.
PH	SA	S	T/TP/O	n/a	n/a	McLeroy, K.	2006	Thinking of Systems.	American Journal of Public Health 96(3): 1 (page numbers (page numbers not finalized)).
PH	SA	S	T/TP/O	n/a	n/a	Mullan, F.	1998	Linda Headrick, MD: Seeking a Common Language in Primary Care.	JAMA 280(7): 655-658.
PH	SA	S	T/TP/O	n/a	n/a	Phillips, D. F.	1999	"New Look" Reflects Changing Style of Patient Safety Enhancement.	JAMA 281(3): 217-219.
PH	SA	S	T/TP/O	n/a	n/a	Radley, A.	1996	Social psychology and health: Framing the relationship.	Psychology & Health 11(5): 629-633.
PH	SA	S	T/TP/O	n/a	n/a	Ross, D. A., A. R. Hinman, et al.	2004	The Near-Term Future for Child Health Information Systems.	Journal of Public Health Management & Practice 10(Suppl.): S99-S104.
PH	SA	S	T/TP/O	n/a	n/a	Shelton, J. D.	2000	The Harm of "First, Do No Harm".	JAMA 284(21): 2687-2688.
PH	SA	S	T/TP/O	n/a	n/a	Wieman, T. J. and E. A. Wieman	2004	A systems approach to error prevention in medicine.	Journal Of Surgical Oncology 88(3): 115-121.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	SA	S	T/TP/O	n/a	n/a	Committee on Assuring the Health of the Public in the 21st Century, Board on Health Promotion and Disease Prevention, et al.	2002	The Future of the Public's Health in the 21st Century.	Washington, DC, The National Academies Press.
PH	SA	S	T/TP/O	n/a	n/a	Murphy-Smith, M., B. Meyer, et al.	2004	Put prevention into practice implementation model: Translating practice into theory.	Journal of Public Health Management & Practice 10(2): 109-115.
PH	SA	S	T/TP/O	n/a	n/a	Health Policy Special Interest Group and International System Dynamics Society	2006	HPSIGWiki: Community Portal. (Website)	Albany, NY, International System Dynamics Society.
PH	OS	S	E	Implementation study	n/a	Ziegenfuss, J. T., R. F. Munzenrider, et al.	1998	Organization change in a university hospital: A six year evaluation report of the HORIZONS project.	Systemic Practice And Action Research 11(6): 575-597.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	E	Qualitative analysis	Over 1000 cities	International Healthy Cities Foundation.	1997 - 2002	Overview and history. (Webpage)	
PH	OS	S	E	Survey; quasi-experimental	49 graduates of a public health leadership school at UNC Chapel Hill, 1 year after graduation	Davis, M. V., W. A. Sollecito, et al.	2004	Examining the Impact of a Distance Education MPH Program: A One-Year Follow-Up Survey of Graduates.	Journal of Public Health Management & Practice 10(6): 556-563.
PH	OS	S	E	Survey; experimental	928 residents of the New York City metropolitan area	Des Jarlais, D. C., S. Galea, et al.	2006	Stigmatization of Newly Emerging Infectious Diseases: AIDS and SARS.	American Journal of Public Health 96(3): (page numbers (page numbers not finalized)).
PH	OS	S	E	Survey	RNs and directors of nursing from 164 nursing homes	Anderson, R. A.; Issel, L. M.; McDaniel, R. R.	2003	Nursing homes as complex adaptive systems - Relationship between management practice and resident outcomes	Nursing Research, 52(1), 12-21.
PH	OS	S	E	Quasi-experimental; survey	420 employees of a health department	Mayer, J. P.	2003	Are the Public Health Workforce Competencies Predictive of Essential Service Performance? A Test at a Large	Journal of Public Health Management & Practice 9(3): 208-213.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
								Metropolitan Local Health Department.	
PH	OS	S	E	Quasi-experimental; survey	315 local public health systems in 7 states	Mays, G. P., M. C. McHugh, et al.	2006	Institutional and Economic Determinants of Public Health System Performance.	American Journal of Public Health 96(3): 1-9 (page numbers (page numbers not finalized)).
PH	OS	S	E	Quasi-experimental; interviews, surveys, qualitative analysis	2 urban community health centers	Lemon, S. C., J. G. Zapka, et al.	2006	Challenges to Research in Urban Community Health Centers.	American Journal of Public Health 96(3): (page numbers (page numbers not finalized)).
PH	OS	S	E	Quasi-experimental; interviews, pre- and post-tests, qualitative analysis	5 district and county health departments in Kentucky	Knight, E. A., F. D. Scutchfield, et al.	2004	Implementing the National Local Public Health System Performance Assessment: Evaluation of a Readiness Process in Kentucky.	Journal of Public Health Management & Practice 10(3): 216-224.
PH	OS	S	E	Quasi-experimental; interviews	679 African American women in one county in North Carolina	James, S. A., A. Fowler-Brown, et al.	2006	Life-course Socioeconomic Position and Obesity in African American Women: The Pitt County Study.	American Journal of Public Health 96(3): (page numbers not finalized).

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	E	Quasi-experimental; interviews	17 community health nurses	John, W. S.	1998	Just what do we mean by community? Conceptualizations from the field.	Health & Social Care In The Community 6(2): 63-70.
PH	OS	S	E	Quasi-experimental; interviews	32 hospital social workers and 18 direct practitioners in Israel	Landau, R.	2000	Ethical dilemmas in general hospitals: Social workers' contribution to ethical decision-making.	Social Work In Health Care 32(2): 75-92.
PH	OS	S	E	Quasi-experimental; cost-effectiveness analysis; pilot programs	n/a	Suba, E. J., S. K. Murphy, et al.	2006	Systems Analysis of Real-World Obstacles to Successful Cervical Cancer Prevention in Developing Countries.	American Journal of Public Health 96(3): (page numbers (page numbers not finalized)).
PH	OS	S	E	quasi-experimental role-play and evaluation	18 participants from a health service	Bryant, J. W. and J. Darwin	2003	Immersive drama: testing health systems.	Omega-International Journal Of Management Science 31(2): 127-136.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	E	quasi-experimental interviews	HIV-positive 10 to 20 year-olds in Brazil and caregivers of patients in the same age group who did not necessarily know the patient's HIV status	Ayres, J. R. d. C. M., V. Paiva, et al.	2006	"Vulnerability, Human Rights, and Comprehensive Health Care Needs of Young People Living With HIV/AIDS."	American Journal of Public Health 96(3): (page numbers not finalized).
PH	OS	S	E	quasi-experimental interviews	424 patients at a Chicago, IL medical center who were at least 18 and spoke fluent English	Baker	2006	A System for Rapidly and Accurately Collecting Patients' Race and Ethnicity.	American Journal of Public Health 96(3): 1-6* (page numbers not finalized).
PH	OS	S	E	Quasi-experimental	2428 adults without a history of heart failure or coronary revascularizat	Cole, C. R., Blackstone, E. H., Pashkow, F. J., Snader, C. E., & Lauer, M. S.	1999	Heart-rate recovery immediately after exercise as a predictor of mortality.	New England Journal Of Medicine, 341(18), 1351-1357.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
					ion and without pacemakers				
PH	OS	S	E	Quasi-experimental	9 organized health delivery systems	Devers, K. J., S. M. Shortell, et al.	1994	Implementing organized delivery systems: An integration scorecard.	Health Care Management Review 19(3): 7.
PH	OS	S	E	Quasi-experimental	25 health care teams	Doran, D. M. I., G. R. Baker, et al.	2002	Achieving clinical improvement: An interdisciplinary intervention.	Health Care Management Review 27(4): 42.
PH	OS	S	E	Quasi-experimental	208 patients at a particular New York City hospital from 1990 to 2003 who suffered subway injuries	Guth, A. A., A. O'Neill, et al.	2006	Public Health Lessons Learned from New York City Subway Injuries.	American Journal of Public Health 96(3): (page numbers not finalized).
PH	OS	S	E	Quasi-experimental	50 local health departments	Honore, P. A., E. J. Simoes, et al.	2004	Applying Principles for Outcomes-Based Contracting in a Public Health Program.	Journal of Public Health Management & Practice 10(5): 451-457.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	E	Quasi-experimental	100 patients with coronary heart disease, 577 survivors of acute infarction, and 614 survivors of acute myocardial infarction	Schmidt, G., Malik, M., Barthel, P., Schneider, R., Ulm, K., Rolnitzky, L., et al.	1999	Heart-rate turbulence after ventricular premature beats as a predictor of mortality after acute myocardial infarction.	Lancet, 353(9162), 1390-1396.
PH	OS	S	E	Qualitative analysis; interviews	A participatory action research project between a consumer group and a public psychiatric hospital in Australia	Wadsworth, Y. and M. Epstein	1998	Building in dialogue between consumers and staff in acute mental health services.	Systemic Practice And Action Research 11(4): 353-379.
PH	OS	S	E	Qualitative analysis; case studies;	Five integrated delivery	Weiner, B., J., L. A. Savitz, et al.	2004	How Do Integrated Delivery Systems Adopt and Implement Clinical Information Systems?	Health Care Management Review 29(1): 51.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
				interviews; surveys	systems				
PH	OS	S	E	Qualitative analysis; case studies	4 families that had a child with cystic fibrosis	Whyte, D. A.	1992	A Family Nursing Approach To The Care Of A Child With A Chronic Illness.	Journal Of Advanced Nursing 17(3): 317-327.
PH	OS	S	E	Qualitative analysis of focus group recommendations	17 "key informants" in public health	Tilson, H. H. and K. Gebbie	2001	Public health physicians: An endangered species.	American Journal of Preventive Medicine 21(3): 233-240.
PH	OS	S	E	Qualitative analysis	A post-merger health care system	Baskin, K., Goldstein, J., & Lindberg, C.	2000	Merging, de-merging, and emerging at deaconess billings clinic.	The Physician Executive, 26(3), 20-25.
PH	OS	S	E	Qualitative analysis	Several contraceptives, both oral and mechanical	Grossman, D., C. Ellertson, et al.	2006	Do Product Labeling and Practice Guidelines Deter Contraceptive Use?	American Journal of Public Health 96(3): (page numbers (page numbers not finalized)).
PH	OS	S	E	Qualitative analysis	The maternal newborn care system in Pennsylvania Hospital	Jones, M. L. H., S. Day, et al.	1999	Implementation of a clinical pathway system in maternal newborn care: A comprehensive documentation system for outcomes management.	Journal Of Perinatal & Neonatal Nursing 13(3): 1-20.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	E	Qualitative analysis	111 primary care practices	Miller, W. L., Crabtree, B. F., McDaniel, R., & Stange, K. C.	1998	Understanding change in primary care practice using complexity theory.	Journal Of Family Practice, 46(5), 369-376.
PH	OS	S	E	Qualitative analysis	The Management Academy for Public Health at UNC Chapel Hill	Porter, J., J. Johnson, et al.	2002	The Management Academy for Public Health: A New Paradigm for Public Health Management Development.	Journal of Public Health Management & Practice 8(2): 66-78.
PH	OS	S	E	Qualitative analysis	A 500-employee urban county health department in Pennsylvania	Potter, M. A., G. Barron, et al.	2003	A Model for Public Health Workforce Development Using the National Public Health Performance Standards Program.	Journal of Public Health Management & Practice 9(3): 199-207.
PH	OS	S	E	Qualitative analysis	3 CDC workforce development programs	Setliff, R., J. E. Porter, et al.	2003	Strengthening the Public Health Workforce: Three CDC Programs that Prepare Managers and Leaders for the Challenges of the 21st Century.	Journal of Public Health Management & Practice 9(2): 91-102.
PH	OS	S	E	Qualitative analysis	A distance-learning masters of public health	Umble, K., S. Shay, et al.	2003	An Interdisciplinary MPH via Distance Learning: Meeting the Educational Needs of Practitioners.	Journal of Public Health Management & Practice 9(2): 123-135.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
					program				
PH	OS	S	E	meta-analysis	Multiple previous studies	Frumkin, H.	2001	Beyond toxicity: Human health and the natural environment.	American Journal of Preventative Medicine, 30(3), 234-244.
PH	OS	S	E	meta-analysis	Scholarly literature about perinatal health	Garfinkel, M. S., D. Sarewitz, et al.	2006	A Societal Outcomes Map for Health Research and Policy.	American Journal of Public Health 396(3): (page numbers (page numbers not finalized)).
PH	OS	S	E	meta-analysis	Scholarly literature	Godin, P. J., & Buchman, T. G.	1996	Uncoupling of biological oscillators: A complementary hypothesis concerning the pathogenesis of multiple organ dysfunction syndrome.	Critical Care Medicine, 24(7), 1107-1116.
PH	OS	S	E	meta-analysis	Hypothetical data set	Muellerleile, P. and B. Mullen	2006	Sufficiency and Stability of Evidence for Public Health Interventions using Cumulative Meta-Analysis.	American Journal of Public Health 96(3): (page numbers (page numbers not finalized)).
PH	OS	S	E	meta-analysis	Multiple previous studies about the Puerto Rican community of	Singer, M.	1996	A dose of drugs, a touch of violence, a case of aids: Conceptualizing the sava syndemic.	Free Inquiry in Creative Sociology, 24(2), 99-110.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
					Hartford, CT				
PH	OS	S	E	meta-analysis	Several studies about community health partnerships and scholarly literature about the subject	Weiner, B. J., J. A. Alexander, et al.	2000	Strategies for effective management participation in community health partnerships.	Health Care Management Review 25(3): 48.
PH	OS	S	E	Focus group analysis	25 people from public health backgrounds	Gebbie, K. M., & Hwang, I.	2000	Preparing currently employed public health nurses for changes in the health system.	American Journal Of Public Health, 90(5), 716-721.
PH	OS	S	E	Experimental design; survey	235 short-term private general hospitals	Jantzen, R. and P. R. Loubeau	1999	Risk-sharing integration efforts in the hospital sector.	Health Care Management Review 24(2): 83.
PH	OS	S	E	Experimental design	Upwards of 14,000 men and women between ages 45 and 65	Dekker, J. M., Crow, R. S., Folsom, A. R., Hannan, P. J., Liao, D.,	2000	Low heart rate variability in a 2-minute rhythm strip predicts risk of coronary heart disease and mortality from several causes - the aric study.	Circulation, 102(11), 1239-1244.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
					without coronary heart disease	Swenne, C. A., et al.			
PH	OS	S	E	Experimental design	114 neonatal intensive care units	Horbar, J. D., J. H. Carpenter, et al.	2004	Collaborative quality improvement to promote evidence based surfactant for preterm infants: a cluster randomised trial.	British Medical Journal 329(7473): 1004-.
PH	OS	S	E	Experimental design	44 private pediatric and family practices in North Carolina	Margolis, P. A., C. M. Lannon, et al.	2004	Practice based education to improve delivery systems for prevention in primary care: randomised trial.	British Medical Journal 328(7436): 388-.
PH	OS	S	E	Concept mapping	172 executive members of patient organizations in the Netherlands	DeRidder, D., Depla, M., Severens, P., & Malsch, M.	1997	Beliefs on coping with illness: A consumer's perspective.	Social Science & Medicine, 44(5), 553-559.
PH	OS	S	E	Concept mapping	34 experts about tobacco industry resistance to tobacco	Trochim, W. M. K., Stillman, F. A., Clark, P. I., & Schmitt, C.	2003	Development of a model of the tobacco industry's interference with tobacco control programmes.	Tobacco Control, 12(2), 140-147.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
					control programs	L.			
PH	OS	S	E	Case Study; Interviews; Qualitative analysis, particpatory methods	A health action zone in London (A Case) studying Systems Research effects	White, L.	2003	The role of systems research and operational research in community involvement: A case study of a health action zone.	Systems Research And Behavioral Science 20(2): 133-145.
PH	OS	S	E	Case study	New York City's 1975 fiscal crisis, and Tuberculosis, HIV, and Homicide syndemic of the 1980's and early 1990's	Freudenberg, N., M. Fahs, et al.	2006	The Impact of New York City's 1975 Fiscal Crisis on the Tuberculosis, HIV, and Homicide Syndemic.	American Journal of Public Health 96(3): 424-434 (page numbers (page numbers not finalized)).
PH	OS	S	E	Case study	Venezuelan public health services	Fuenmayor, A. and R. Fuenmayor	1999	Researching-acting-reflecting on public health services in Venezuela. II. Community	Systemic Practice And Action Research 12(1): 55-75.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
								action and critique.	
PH	OS	S	E	Case study	Traffic volume data and addresses of licensed childcare facilities in Los Angeles	Ong, P., M. Graham, et al.	2006	Policy and Programmatic Importance of Spatial Alignment of Data Sources.	American Journal of Public Health 96(3): 66-71 (page numbers (page numbers not finalized)).
PH	OS	S	E	Case history	One family in which several members had a hereditary disease	Clark, M. W.	2002	The Human Genome: One Family's Journey.	Journey of Systemic Therapies 21(2): 41-54.
PH	OS	S	M	n/a	n/a	Hirsch, G. and C. S. Immediato	1999	Microworlds and generic structures as resources for integrating care and improving health.	System Dynamics Review 15(3): 315-330.
PH	OS	S	M	n/a	n/a	Homer, J., J. Ritchie-Dunham, et al.	2000	Toward a dynamic theory of antibiotic resistance.	System Dynamics Review 16(4): 287-319.
PH	OS	S	M	n/a	n/a	Sterman, J. D.	2006	Learning from Evidence in a Complex World.	American Journal of Public Health 96(3): 1-10 (page numbers (page numbers not finalized)).

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	M	Concept mapping	11 groups of stakeholders	Batterham, R., Southern, D., Appleby, N., Elsworth, G., Fabris, S., Dunt, D., et al.	2002	Construction of a gp integration model.	Social Science & Medicine
PH	OS	S	T/TP/O	n/a	n/a	Centers for Disease Control and Prevention and National Center for Chronic Disease Prevention and Health Promotion	2005	Spotlight on Syndemics. (Webpage)	Washington, DC, Centers for Disease Control and Prevention.
PH	OS	S	T/TP/O	recommendations based on empirical findings from other studies	n/a	Ashmos, D. P., Duchon, D., & McDaniel, R. R.	2000	Physicians and decisions: A simple rule for increasing connections in hospitals.	Health Care Management Review 25(1): 109-115.
PH	OS	S	T/TP/O	n/a	n/a	Anderson, R. A., & McDaniel, R. R.	2000	Managing health care organizations: Where professionalism meets complexity science.	Health Care Management Review 25(1): 83-92.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	T/TP/O	n/a	n/a	Barnsley, J., L. Lemieux-Charles, et al.	1998	Integrating learning into integrated delivery systems.	Health Care Management Review 23(1): 18.
PH	OS	S	T/TP/O	n/a	n/a	Bar-Yam, Y.	2006	Improving the Effectiveness of Health Care and Public Health: A Multiscale Complex Systems Analysis.	American Journal of Public Health 96(3): 459-466* (page numbers not finalized).
PH	OS	S	T/TP/O	n/a	n/a	Begun, J. W., Zimmerman, B., & Dooley, K.	2003	Health care organizations as complex adaptive systems.	S. S. Mick & M. E. Wyttenbach (Eds.), Advances in health care organization theory. San Fransisco, CA: Jossey-Bass.
PH	OS	S	T/TP/O	n/a	n/a	Berwick, D. M.	1997	Medical associations: guilds or leaders?	British Medical Journal 314(7094): 1564-.
PH	OS	S	T/TP/O	n/a	n/a	Chino, M. and L. DeBruyn	2006	Building True Capacity: Indigenous Models for Indigenous Communities.	American Journal of Public Health 96(3): (page numbers (page numbers not finalized)).
PH	OS	S	T/TP/O	n/a	n/a	Clark, P. I., & Djordjevic, M. J.	2003	The role of smoking topography in assessing human smoking and its utility for informing machine-smoking protocols.	no information available
PH	OS	S	T/TP/O	n/a	n/a	Daniels, N.	2006	Toward Ethical Review of Health System Transformations.	American Journal of Public Health 96(3): 14-18 (page numbers (page numbers not finalized)).

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	T/TP/O	n/a	n/a	Dardik, I. I.	1997	The origin of disease and health, heart waves: The single solution to heart rate variability and ischemic preconditioning the origin of disease and health, heart waves: The single solution to heart rate variability and ischemic preconditioning.	Frontier Perspectives, 6(2), 18-32.
PH	OS	S	T/TP/O	n/a	n/a	Fajans, P., R. Simmons, et al.	2006	Helping Public Sector Health Systems Innovate: The Strategic Approach to Strengthening Reproductive Health Policies and Programs.	American Journal of Public Health 96(3): (page numbers (page numbers not finalized)).
PH	OS	S	T/TP/O	n/a	n/a	Glouberman, S., & Zimmerman, B.	2002	Complicated and complex systems: What would successful reform of medicare look like?	Commission on the Future of Health Care in Canada.
PH	OS	S	T/TP/O	n/a	n/a	Goldberger, A. L.	1996	Non-linear dynamics for clinicians: Chaos theory, fractals, and complexity at the bedside.	Lancet, 347(9011), 1312-1314.
PH	OS	S	T/TP/O	n/a	n/a	Goldberger, A. L.	1997	Fractal variability versus pathologic periodicity: Complexity loss and stereotypy in disease.	Perspectives In Biology And Medicine, 40(4), 543-561.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	T/TP/O	n/a	n/a	Goldberger, A. L., Rigney, D. R., & West, B. J.	1990	Chaos and fractals in human physiology.	Scientific American, 262(2), 43-49.
PH	OS	S	T/TP/O	n/a	n/a	Goodwin, J. S.	1997	A piece of my mind. Chaos, and the limits of modern medicine.	Journal Of The American Medical Association, 278(17), 1399-1400.
PH	OS	S	T/TP/O	n/a	n/a	Green, L. W.	1970	Should health education abandon attitude change strategies: Perspectives from recent research.	Health Education Monographs, 1(30), 25-48.
PH	OS	S	T/TP/O	n/a	n/a	Green, L. W., McGinnis, M., Phillips, T. S., Devereaux, M., & Montes, H.	1987	Strategies for promoting health for specific populations	(No. DHHS (PHS) Publication No. 81 50169). Washington, DC: US Office of Health Information and Health Promotion.
PH	OS	S	T/TP/O	n/a	n/a	Hammett, T. M.	2006	HIV/AIDS and Other Infectious Diseases Among Correctional Inmates: Transmission, Burden, and Appropriate Response.	American Journal of Public Health 96(3): 13-17 (page numbers (page numbers not finalized))
PH	OS	S	T/TP/O	n/a	n/a	Hoffmann, D., & Hoffmann, I.	1997	The changing cigarette, 1950-1995.	Journal Of Toxicology And Environmental Health, 50(4), 307-364.
PH	OS	S	T/TP/O	n/a	n/a	Institute for Healthcare	2005	About us. (webpage)	

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
						Improvement.			
PH	OS	S	T/TP/O	n/a	n/a	Ivanov, P. C., Amaral, L. A. N., Goldberger, A. L., Havlin, S., Rosenblum, M. G., Struzik, Z. R., et al.	1999	Multifractality in human heartbeat dynamics.	Nature, 399(6735), 461-465.
PH	OS	S	T/TP/O	n/a	n/a	Joffe, M. and J. Mindell	2006	Complex Causal Process Diagrams for Analyzing the Health Impacts of Policy Interventions.	American Journal of Public Health 96(3): 40-46 (page numbers (page numbers not finalized)).
PH	OS	S	T/TP/O	n/a	n/a	Levy, D. T., J. E. Bauer, et al.	2006	Simulation Modeling and Tobacco Control: Creating More Robust Public Health Policies.	American Journal of Public Health 96(3): 61-65 (page numbers (page numbers not finalized)).
PH	OS	S	T/TP/O	n/a	n/a	Lipsitz, L. A., & Goldberger, A. L. *LOOK UP IN BINDER	1992	Loss of complexity and aging - potential applications of fractals and chaos theory to senescence.	Journal Of The American Medical Association, 267(13), 1806-1809.
PH	OS	S	T/TP/O	n/a	n/a	U.S. Dept. of HEW (Public Health	1964	Smoking and health: Report of the advisory committee to the surgeon general of the public	(No. 1103). Washington, DC.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
						Service).		health service	
PH	OS	S	T/TP/O	n/a	n/a	Umble, K., Steffen, D., Porter, J., Miller, D., Hummer-McLaughlin, K., Lowman, A., et al.	2005	The national public health leadership institute: Evaluation of a team-based approach to developing collaborative public health leaders.	American Journal Of Public Health, 95(4), 641-644.
PH	OS	S	T/TP/O	n/a	n/a	University of Washington.	2005	Community-campus partnerships for health home page.	
PH	OS	S	T/TP/O	n/a	n/a	University of Washington.	2005	Community-campus partnerships for health: About us.	
PH	OS	S	T/TP/O	n/a	n/a	Wakefield, M. A., Terry-McElrath, Y. M., Chaloupka, F. J., Barker, D. C., Slater, S. J., Clark, P. I., et al.	2002	Tobacco industry marketing at point of purchase after the 1998 msa billboard advertising ban.	American Journal Of Public Health, 92(6), 937-940.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	T/TP/O	n/a	n/a	Weibel, E. R.	1991	Fractal geometry - a design principle for living organisms.	American Journal Of Physiology, 261(6), L361-L369.
PH	OS	S	T/TP/O	n/a	n/a	Cooney, M. M.	1995	Managed Health-Care - Managing The Risks Of Laboratory Testing In An Integrated Delivery System.	American Journal Of Clinical Pathology 104(4): S50-S53.
PH	OS	S	T/TP/O	n/a	n/a	Davies, H. T. O. and S. M. Nutley	2000	Developing learning organisations in the new NHS.	British Medical Journal 320(7240): 998-1001.
PH	OS	S	T/TP/O	n/a	n/a	Donaldson, L.	2004	When will health care pass the orange-wire test?	The Lancet 364(9445): 1567.
PH	OS	S	T/TP/O	n/a	n/a	Edwards, N., J. Mill, et al.	2004	Multiple intervention research programs in community health.	Canadian Journal of Nursing Research 36(1): 40-54.
PH	OS	S	T/TP/O	n/a	n/a	Finlayson, B. and S. Dewar	2001	Reforming complaints systems: UK and New Zealand.	The Lancet 358(9290): 1290.
PH	OS	S	T/TP/O	n/a	n/a	Fuenmayor, R. and A. Fuenmayor	1999	Researching-acting-reflecting on public health services in Venezuela. I. A conceptual framework.	Systemic Practice And Action Research 12(1): 35-53.
PH	OS	S	T/TP/O	n/a	n/a	Gerberding, J. L.	2005	Protecting Health--The New Research Imperative.	Journal of the American Medical Association 294(11): 1403-1406.
PH	OS	S	T/TP/O	n/a	n/a	Illich, I.	1995	Death undefeated.	British Medical Journal 311(7021): 1652-1653.
PH	OS	S	T/TP/O	n/a	n/a	Leape, L. L. and D. M.	2000	Safe health care: are we up to it?	British Medical Journal 320(7237): 725-726.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
						Berwick			
PH	OS	S	T/TP/O	n/a	n/a	Lenihan, P.	2005	MAPP and the Evolution of Planning in Public Health Practice.	Journal of Public Health Management & Practice 11(5): 381-388.
PH	OS	S	T/TP/O	n/a	n/a	Macdonald, G.	2002	Transformative unlearning: safety, discernment and communities of learning.	Nursing Inquiry 9(3): 170-178.
PH	OS	S	T/TP/O	n/a	n/a	Moody, R. C.	2004	Nurse Productivity Measures for the 21st Century.	Health Care Management Review 29(2): 98.
PH	OS	S	T/TP/O	n/a	n/a	Pinkerton, S.	2004	Early Bar Code Ruling Helps Reduce Medication Errors.	Health Care Management Review 29(2): 89.
PH	OS	S	T/TP/O	n/a	n/a	Pruitt, S. D. and J. E. Epping-Jordan	2005	Preparing the 21st century global healthcare workforce.	British Medical Journal 330(7492): 637-639.
PH	OS	S	T/TP/O	n/a	n/a	Rowitz, L.	2004	Ten tools for practice learning.	Journal of Public Health Management & Practice 10(4): 368-370.
PH	OS	S	T/TP/O	n/a	n/a	Royston, G.	1998	Shifting the balance of health care into the 21st century.	European Journal Of Operational Research 105(2): 267-276.
PH	OS	S	T/TP/O	n/a	n/a	Shah, M. N.	2006	The Formation of the Emergency Medical Services System.	American Journal of Public Health 96(3): (page numbers (page numbers not finalized)).

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	T/TP/O	n/a	n/a	Singer, M., & Clair, S.	2003	Syndemics and public health: Reconceptualizing disease in bio-social context.	Medical Anthropology Quarterly, 17(4), 423-441.
PH	OS	S	T/TP/O	n/a	n/a	Singer, M., & Snipes, C.	1992	Generations of suffering: Experiences of a treatment program for substance abuse during pregnancy.	Journal of Health Care for the Poor and Underserved, 3(1), 222-234.
PH	OS	S	T/TP/O	n/a	n/a	Smith, R.	2003	What doctors and managers can learn from each other.	BMJ 326(7390): 610-611.
PH	OS	S	T/TP/O	n/a	n/a	Stokols, D., Pelletier, K. R., & Fielding, J. E.	1996	The ecology of work and health: Research and policy directions for the promotion of employee health.	Health Education Quarterly, 23(2), 137-158.
PH	OS	S	T/TP/O	n/a	n/a	Storch, J. L.	1999	Is practical nursing experience necessary in administration, education, and research?	Western Journal Of Nursing Research 21(1): 83-93.
PH	OS	S	T/TP/O	n/a	n/a	Syme, S. L., & Balfour, J. L.	1998	Social determinants of disease.	In R. B. Wallace (Ed.), Maxey-rosenau-last public health & preventive medicine (14th ed., pp. 795-810). Stamford,CT: McGraw-Hill Professional.
PH	OS	S	T/TP/O	n/a	n/a	Triolo, P. K., B. J. Pozehl, et al.	1997	Development of leadership within the university and beyond: Challenges to faculty and their development.	Journal Of Professional Nursing 13(3): 149-153.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	T/TP/O	n/a	n/a	Trochim, W. M. and M. Kane	2005	Concept mapping: an introduction to structured conceptualization in health care.	International Journal For Quality In Health Care 17(3): 187-191.
PH	OS	S	T/TP/O	n/a	n/a	Wilson, A. and H. Jarman	2002	Private practice -- An advanced practice option.	Contemporary Nurse 13 (2-3): 209-216.
PH	OS	S	T/TP/O	n/a	n/a	Wright, K., Rowitz, L., Merkle, A., Reid, W. M., Robinson, G., Herzog, B., et al.	2000	Competency development in public health leadership.	American Journal Of Public Health, 90(8), 1202-1207.
PH	OS	S	T/TP/O	n/a	n/a	Wynder, E. L., & Hoffmann, D.	1994	Smoking and lung-cancer - scientific challenges and opportunities.	
PH	OS	S	T/TP/O	n/a	n/a	Zimmerman, B., Lindberg, C., & Plsek, P. E.	2001	Edgeware: Lessons from complexity science for health care leaders.	Dallas, TX: VHA, Inc.
PH	OS	S	T/TP/O			Burke, J. P. and S. L. Pestotnik	2000	Antibiotic cycling: what goes around come around.	Current Opinion in Infectious Diseases 13(4): 367-369.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	T/TP/O	n/a	n/a	Centers for Disease Control and Prevention and National Center for Chronic Disease Prevention and Health Promotion	2002	Introduction to the syndemics prevention network.	Atlanta, GA, CDC.
PH	OS	S	T/TP/O	n/a	n/a	Corso, L. C., P. J. Wiesner, et al.	2005	Developing the MAPP Community Health Improvement Tool.	Journal of Public Health Management & Practice 11(5): 387-392.
PH	OS	S	T/TP/O	n/a	n/a	Milstein, B.	2004	Syndemics.	In S. Mathison (Ed.), Encyclopedia of evaluation (pp. 404-405). Thousand Oaks, CA: Sage Publications, Inc.
PH	OS	S	T/TP/O	n/a	n/a	Partnership for the Public's Health.	2005	About the partnership: Overview. (Webpage)	
PH	OS	S	T/TP/O	n/a	n/a	U.S. Department of Health and Human Services.	2005	Healthy people 2010: The cornerstone for prevention.	Rockville, MD: U.S. Government Printing Office.

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	T/TP/O	n/a	n/a	U.S. Department of Health and Human Services.	2000	Healthy people 2010: Understanding and improving health, 2nd ed.	Washington, DC: U.S. Government Printing Office.
PH	OS	S	T/TP/O	n/a	n/a	U.S. Department of Health and Human Services.	2001	Healthy people in healthy communities: A community planning guide using healthy people 2010.	Rockville, MD: U.S. Government Printing Office.
PH	OS	S	T/TP/O	n/a	n/a	U.S. Department of Health and Human Services.	2003	Creating partnerships, improving health: The role of community-based participatory research	(No. AHRQ Pub. No. 03-0037). Washington, DC.: U.S. Government Printing Office.
PH	OS	S	T/TP/O	n/a	n/a	W.K. Kellogg Foundation.	1998	Partnerships: A powerful tool for improving the well-being of families and neighborhoods, final review version.	Battle Creek, MI: W.K. Kellogg Foundation.
PH	OS	S	T/TP/O	n/a	n/a	Wilson, J.	2002	Leadership development: Working together to enhance collaboration.	Journal of Public Health Management & Practice 8(1): 21-26.
PH	OS	S	T/TP/O	n/a	n/a	World Health Organization.	2005	Commission on social determinants of health. (Webpage)	

Topical Focus (general)	Topical Focus (specific)	Topical Focus (ST)	Method (general)	Method (specific)	Sample	Author(s)	Year	Title	Book/Journal Info
PH	OS	S	T/TP/O	n/a	n/a	World Health Organization.	2000	World health report 2000: Health systems: Improving performance	(No. 924156198X). Geneva, Switzerland: World Health Organization.
PH	OS	S	T/TP/O	n/a	n/a	Turning Point National Program Office.	2003	From silos to systems: Performance management to improve the public's health.	Seattle, WA: Turning Point Performance Management Collaborative, Public Health Foundation.

APPENDIX 5A: Text for Email Sent to Participants

----- Original Message -----

From: [redacted]

Sent: Sunday, December 19, 2004 11:05 PM

Subject: An Invitation: Concept Mapping for Systems Thinking and Modeling in Public Health

Dear Colleague,

You are invited to participate in a unique effort to expand the role of systems thinking and modeling in the field of public health. In 2005, the American Journal of Public Health will publish a special issue devoted to the theme of systems thinking and modeling (see: http://www.cdc.gov/syndemics/ajph-systems.htm). One of the featured essays intended for this publication will explore the structural conditions that support the use a systems orientation for public health work. Because of your interest and familiarity in this area, I invite you to participate in a web-based concept mapping project to explore the practical challenges that need to be addressed to encourage and support effective systems thinking and modeling in public health work.

This project will use the concept mapping methodology for structured conceptualization and will be entirely conducted over the web. Concept mapping is a systems planning, research, and design tool for obtaining conceptual information from a group of participants about any topic of interest. This project has been designed to minimize the demands on your time. I estimate that it will take only 15-20 minutes between now and January 15, followed by an additional 60-90 minutes between January 15-31. All activities take place over the Internet at a time of your choosing, using the online concept mapping software. You may elect to participate in either or both phases of the project.

Phase I (now through January 15) focuses on brainstorming a list of practical challenges. Phase II (January 15-31) asks you to sort and rate those ideas. Both steps are entirely voluntary and anonymous. Input will be pooled across participants and used to create detailed maps of the conditions that support a systems orientation. All results will be made available to participants through a website report. The benefits of your participation are that you will be able to influence the results of this important effort and will be informed about all results.

To participate in this project, please do following no later than January 15:

1. Think of ideas to complete to the following statement:

"One specific practical challenge that needs to be addressed to encourage and support effective systems thinking and modeling in public health work is... "

2. Submit your ideas anonymously at the following web page:
http://www.[redacted]

More information about this project and the concept mapping methodology is available at this website. I will contact you again in early January to give you instructions for the second and final phase of the project.

If you have any questions, please feel free to contact me directly at [redacted] or write to: [redacted]. Or, you may contact [redacted]

If you know of anyone else who might like to participate, please send me their e-mail address (or have them send it) so I can put them on my list, and send them an invitation and follow-up messages.

Thanks in advance for your time and interest.

APPENDIX 5B: Text for Brainstorming Web Page

Welcome to the project on Systems Thinking and Modeling in Public Health. The purpose of this pilot project is to identify the major challenges that need to be addressed in order to encourage and support effective use of systems thinking and modeling in public health. From now until the end of the year we will be gathering your ideas in a web-based brainstorming process. In the first two weeks of January we will be asking you to organize and rate the ideas. We will then analyze your input and provide detailed maps of the challenges that need to be addressed. In this project we will be using a concept mapping methodology (for more information about concept mapping, see http://www.socialresearchmethods.net/mapping/mapping.htm). All results will be made available to participants through a website report. Your participation in this project will be anonymous.

1. Think of 5 – 10 responses to the following statement:

   "One specific practical challenge that needs to be addressed to encourage and support effective systems thinking and modeling in public health work is..."

Ready to start??? --> **Brainstorm**
We provide definitions for the major terms in the focus prompt below. If you have any questions or concerns, please feel free to contact [redacted] Thanks for your participation.

Definitions of key terms in the focus prompt:
One specific practical challenge that needs to be addressed to encourage and support effective systems thinking and modeling in public health work is...

Practical Challenge
A practical challenge is a challenge that can be operationalized as a specific action or set of actions that can reasonably be undertaken within the forseeable future. Vague, general statements of philosophy are usually not 'practical.' While a statement like 'eliminate sickness' is certainly a challenge, it is not practical in the sense that one cannot act on it directly. However, it is certainly possible to think of any number of practical challenges that would help us to work towards 'eliminating sickness', any of which would be 'practical' (e.g., discover new treatments, fund research, identify clinician practice needs, etc.). In brainstorming we would like participants to generate ideas without constraint. Therefore, when in doubt, err on the side of entering a statement rather than omiting it.

Systems Thinking and Modeling
The "thinking" part of systems thinking and modeling refers to conceptual orientations wherein one acknowledges the importance of relationships, trying never to regard anything outside of its connection to other things. The same idea is sometimes referred

to as "ecological thinking." Which specific relationships are of interest may vary depending on circumstances (e.g., some approaches focus on actors/organizations in a network, others examine the causal dynamics of variables on one another, still others concentrate on the direction of movement relative to a goal, etc...). The distinguishing feature in all forms of systems thinking is their commitment to perceiving important relationships, including those that are indirect or separated in time and space from the health events that people experience. The "modeling" part of systems thinking and modeling refers to methodological orientations wherein one's thoughts about systems are made explicit and rendered open to scrutiny by oneself and others (e.g., through the use of matrix algebra to study the structure of a network, or the use of differential equations to build a computer simulation, or the plotting of measured indicators to chart progress toward a goal, etc...). The distinguishing feature in all forms of systems modeling is their attempt to formalize the structure and behavior of system as a means for improving learning and action.

Public Health Work

Public health work is sustained, visible, serious effort by a diverse mix of citizens that assures the conditions in which people can be healthy. Whereas patients need a doctor's care only occasionally to treat sickness and regain health, people must work all the time to guard against affliction and protect their individual and collective well-being. An immense range of activities, carried out by an equally diverse range of actors, contributes to the overall public health enterprise (e.g., surveillance, research, policy development, program delivery, education, law enforcement, evaluation, personal health behavior, and more).

APPENDIX 5C: Phase 2 Email to Participants

----- Original Message -----
From: [redacted]
To: [redacted]
Sent: Monday, January 24, 2005 2:32 PM
Subject: Systems Thinking & Modeling in Public Health Study Phase 2

Systems Thinking & Modeling in Public Health Study Phase 2

Dear Colleague,

Thanks to you and your colleagues, the brainstorming part of the concept-mapping project is complete. As you might recall we asked you to generate responses to the following statement: "One specific practical challenge that needs to be addressed to encourage and support effective systems thinking and modeling in public health work is." We received over 315 ideas. Your contributions were crucial to the successful completion of this phase of the project, and we thank you for your time and participation.

We now invite you to participate in the second phase of the project. This phase, organizing and rating of the final set of ideas, is one of the most critical steps in the process. We estimate that it may take you between 45-60 minutes to perform all three tasks.

The following is what we are asking you to do by February 7th:

1. Demographics: Please provide a few general non-identifying descriptive questions about yourself. (Approximate time to complete: 1 minute)

2. Sorting: Sort each of the idea statements into groups that are similar in meaning. (Approximate time to complete: 30-40 minutes)

3. Rating: Rate each of the idea statements according to how important it is (compared to the other statements) in terms of being a challenge that must be addressed to encourage and support systems thinking and modeling in public health. (Approximate time to complete: 10-15 minutes)

You may choose from two options for the completion of Phase 2:

The first option is to complete the activities by February 7th on the Worldwide Web. The web address is:

http://www.[redacted]

Your UserName is: [redacted] Your Password is: [redacted]

The second option is to download a file (in Adobe PDF format) that you can print, fill out and fax to [redacted] by February 7th. You can access this file at the following website:

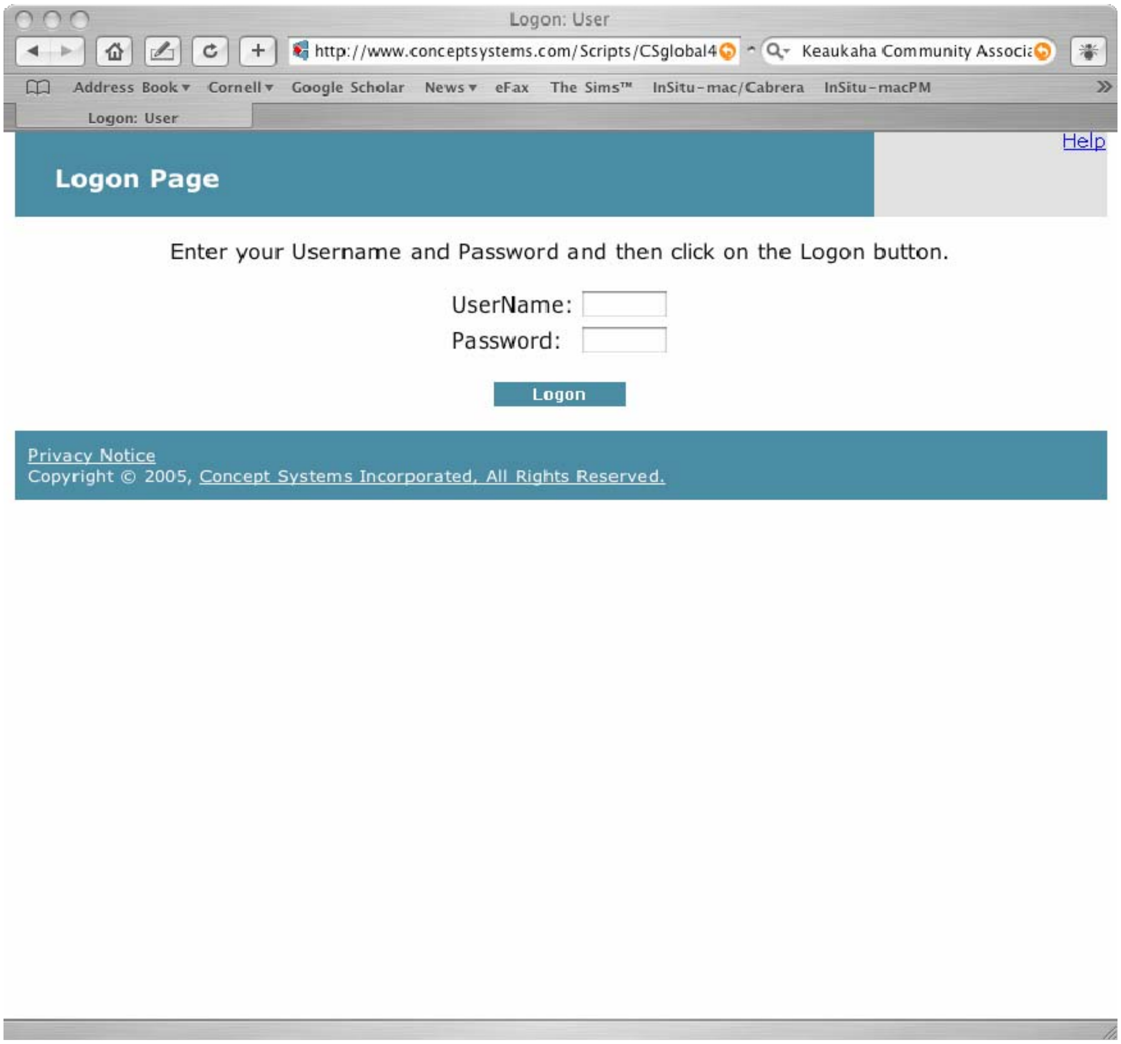
http://www.conceptsystems.com/projects/PHSystems/phase2manual.htm

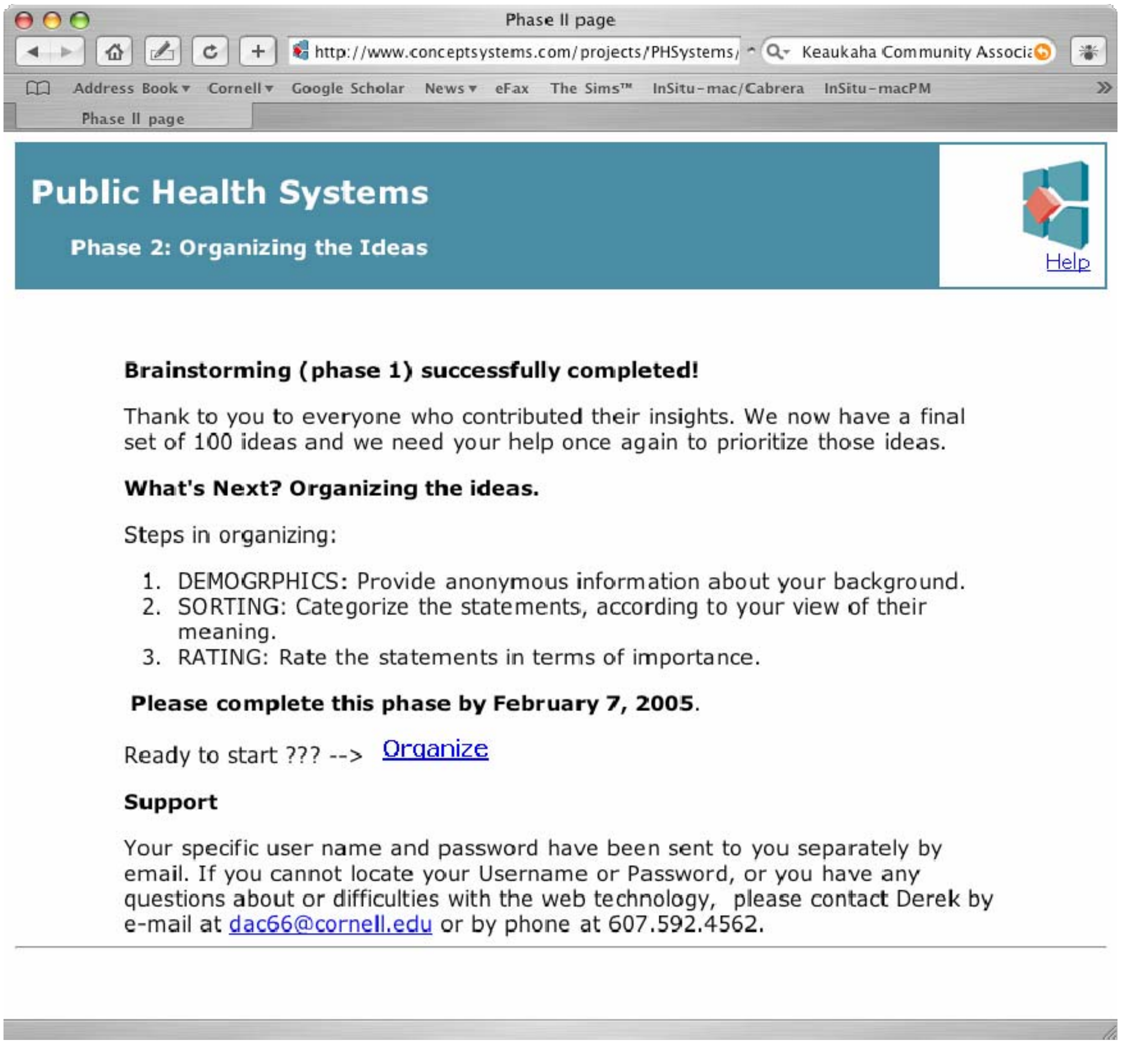
Please contact [redacted] with any questions. Thank you in advance for your participation.

Sincerely,

[redacted]

APPENDIX 5D: Web Pages Seen by Participants





Phase II page

http://www.conceptsystems.com/projects/PHSystems/

Keaukaha Community Associa

Address Book ▾ Cornell ▾ Google Scholar News ▾ eFax The Sims™ InSitu-mac/Cabrera InSitu-macPM

Phase II page

Public Health Systems

Phase 2: Organizing the Ideas

Help

Brainstorming (phase 1) successfully completed!

Thank to you to everyone who contributed their insights. We now have a final set of 100 ideas and we need your help once again to prioritize those ideas.

What's Next? Organizing the ideas.

Steps in organizing:

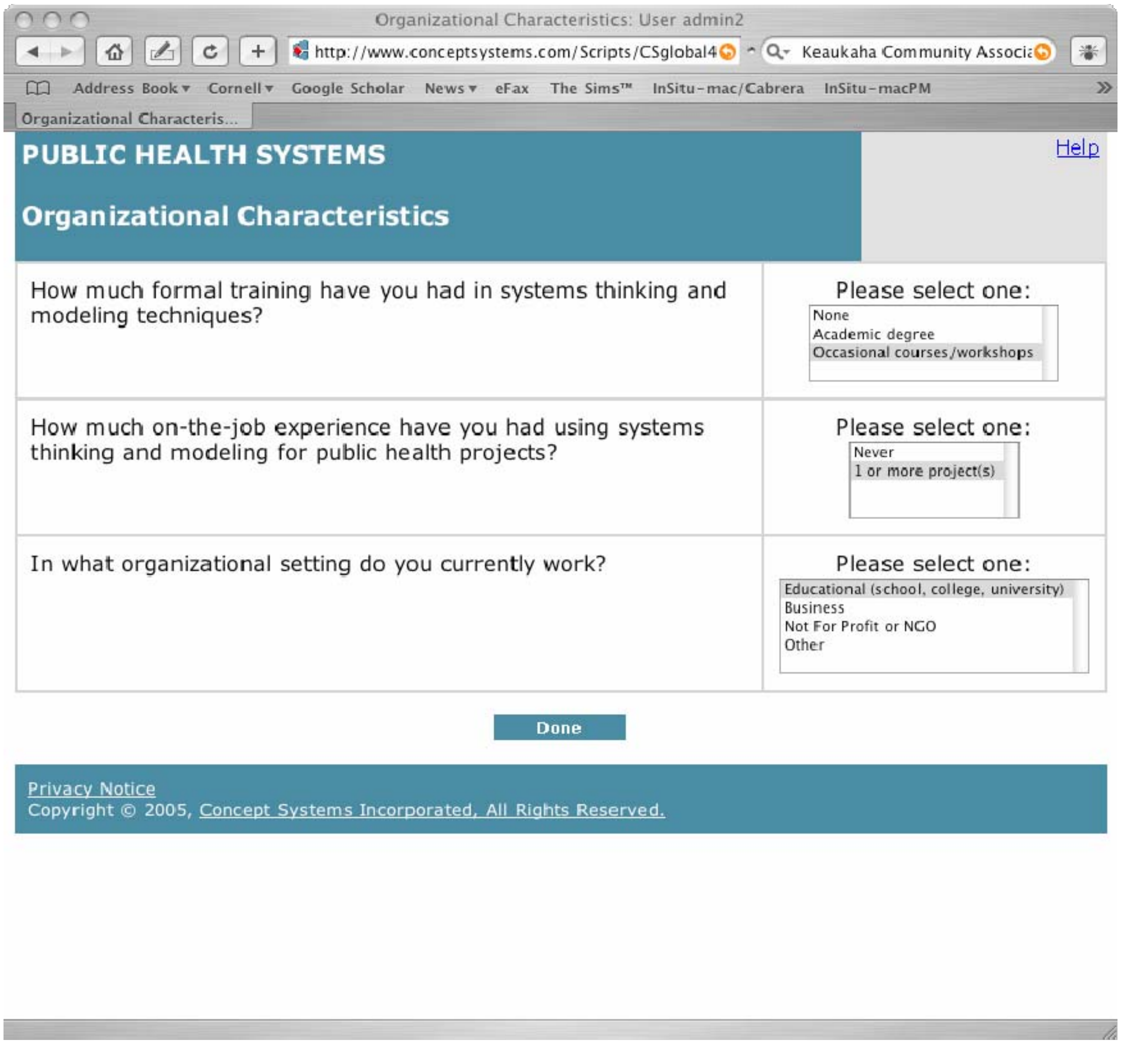
1. DEMOGRPHICS: Provide anonymous information about your background.
2. SORTING: Categorize the statements, according to your view of their meaning.
3. RATING: Rate the statements in terms of importance.

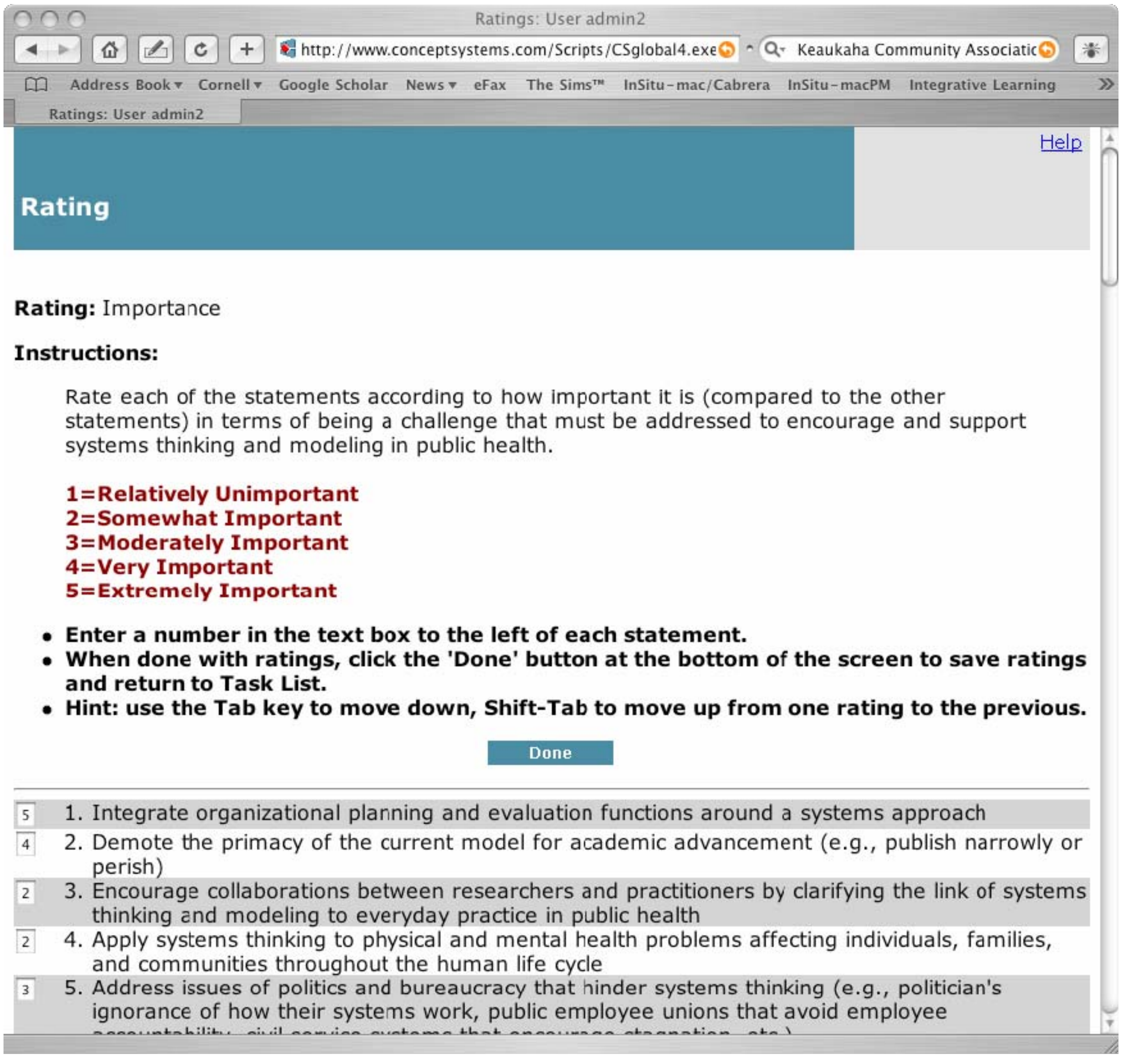
Please complete this phase by February 7, 2005.

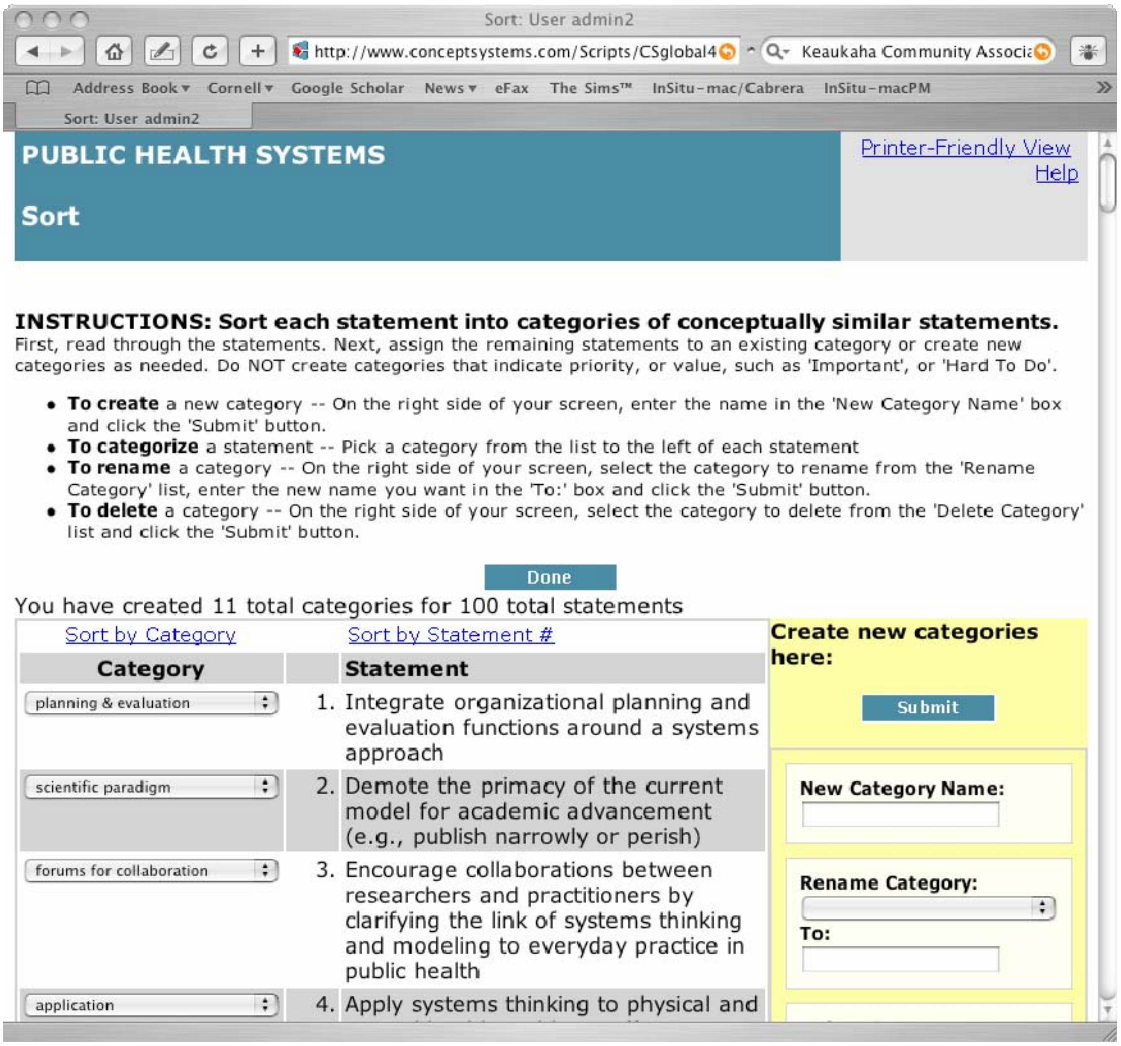
Ready to start ??? --> Organize

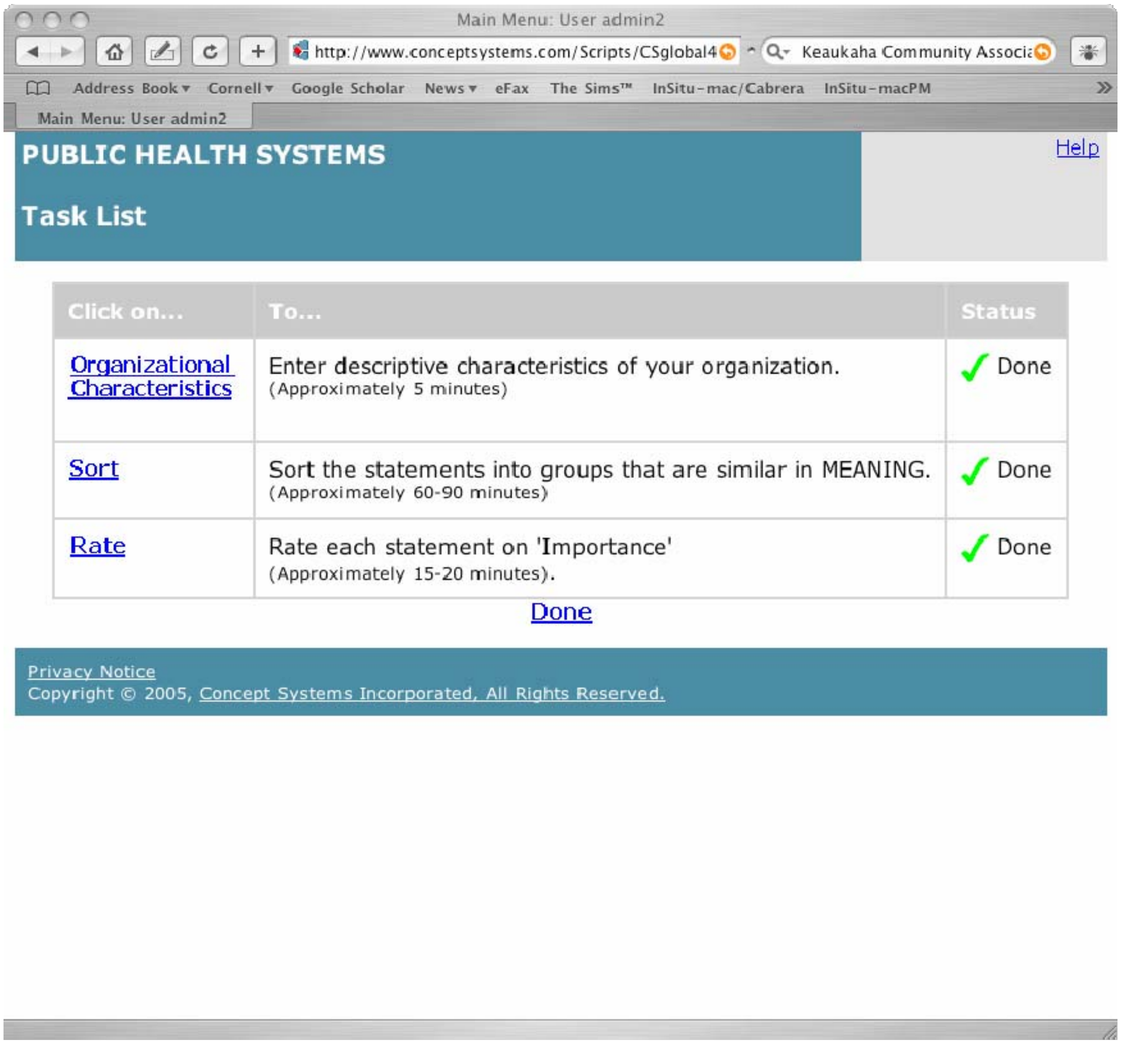
Support

Your specific user name and password have been sent to you separately by email. If you cannot locate your Username or Password, or you have any questions about or difficulties with the web technology, please contact Derek by e-mail at dac66@cornell.edu or by phone at 607.592.4562.


Organizational Characteristics: User admin2
http://www.conceptsystems.com/Scripts/CSglobal4
Keaukaha Community Associa
Address Book
Cornell
Google Scholar
News
eFax
The Sims™
InSitu-mac/Cabrera
InSitu-macPM
Organizational Characteris...
PUBLIC HEALTH SYSTEMS
Organizational Characteristics
Help
How much formal training have you had in systems thinking and modeling techniques?
Please select one:
None
Academic degree
Occasional courses/workshops
How much on-the-job experience have you had using systems thinking and modeling for public health projects?
Please select one:
Never
1 or more project(s)
In what organizational setting do you currently work?
Please select one:
Educational (school, college, university)
Business
Not For Profit or NGO
Other
Done
Privacy Notice
Copyright © 2005, Concept Systems Incorporated, All Rights Reserved.


Ratings: User admin2
http://www.conceptsystems.com/Scripts/CSglobal4.exe
Keaukaha Community Associatio
Address Book
Cornell
Google Scholar
News
eFax
The Sims™
InSitu-mac/Cabrera
InSitu-macPM
Integrative Learning
Ratings: User admin2
Help
Rating
Rating: Importance
Instructions:
Rate each of the statements according to how important it is (compared to the other statements) in terms of being a challenge that must be addressed to encourage and support systems thinking and modeling in public health.
1=Relatively Unimportant
2=Somewhat Important
3=Moderately Important
4=Very Important
5=Extremely Important
• Enter a number in the text box to the left of each statement.
• When done with ratings, click the 'Done' button at the bottom of the screen to save ratings and return to Task List.
• Hint: use the Tab key to move down, Shift-Tab to move up from one rating to the previous.
Done
5 1. Integrate organizational planning and evaluation functions around a systems approach
4 2. Demote the primacy of the current model for academic advancement (e.g., publish narrowly or perish)
2 3. Encourage collaborations between researchers and practitioners by clarifying the link of systems thinking and modeling to everyday practice in public health
2 4. Apply systems thinking to physical and mental health problems affecting individuals, families, and communities throughout the human life cycle
3 5. Address issues of politics and bureaucracy that hinder systems thinking (e.g., politician's ignorance of how their systems work, public employee unions that avoid employee


Sort: User admin2
http://www.conceptsystems.com/Scripts/CSglobal4
Keaukaha Community Associa
Address Book
Cornell
Google Scholar
News
eFax
The Sims™
InSitu-mac/Cabrera
InSitu-macPM
Sort: User admin2
PUBLIC HEALTH SYSTEMS
Sort
Printer-Friendly View
Help
INSTRUCTIONS: Sort each statement into categories of conceptually similar statements.
First, read through the statements. Next, assign the remaining statements to an existing category or create new categories as needed. Do NOT create categories that indicate priority, or value, such as 'Important', or 'Hard To Do'.
To create a new category -- On the right side of your screen, enter the name in the 'New Category Name' box and click the 'Submit' button.
To categorize a statement -- Pick a category from the list to the left of each statement
To rename a category -- On the right side of your screen, select the category to rename from the 'Rename Category' list, enter the new name you want in the 'To:' box and click the 'Submit' button.
To delete a category -- On the right side of your screen, select the category to delete from the 'Delete Category' list and click the 'Submit' button.
Done
You have created 11 total categories for 100 total statements
Sort by Category
Sort by Statement #
Category
Statement
planning & evaluation
1. Integrate organizational planning and evaluation functions around a systems approach
scientific paradigm
2. Demote the primacy of the current model for academic advancement (e.g., publish narrowly or perish)
forums for collaboration
3. Encourage collaborations between researchers and practitioners by clarifying the link of systems thinking and modeling to everyday practice in public health
application
4. Apply systems thinking to physical and
Create new categories here:
Submit
New Category Name:
Rename Category:
To:


Main Menu: User admin2
http://www.conceptsystems.com/Scripts/CSglobal4
Keaukaha Community Associa
Address Book
Cornell
Google Scholar
News
eFax
The Sims™
InSitu-mac/Cabrera
InSitu-macPM
Main Menu: User admin2
PUBLIC HEALTH SYSTEMS
Task List
Help
Click on...
To...
Status
Organizational Characteristics
Enter descriptive characteristics of your organization.
(Approximately 5 minutes)
Done
Sort
Sort the statements into groups that are similar in MEANING.
(Approximately 60-90 minutes)
Done
Rate
Rate each statement on 'Importance'
(Approximately 15-20 minutes).
Done
Done
Privacy Notice
Copyright © 2005, Concept Systems Incorporated, All Rights Reserved.

APPENDIX 5E: Original Brainstormed Statements and Phylogenic Path

Phylogeny	Final Number	Randomized Sequence of Final Statements
195.12.34.32.	1	Integrate organizational planning and evaluation functions around a systems approach
236	2	Demote the primacy of the current model for academic advancement (e.g., publish narrowly or perish)
315.86.129.53.274158.25.44.214.215.288.67.	3	Encourage collaborations between researchers and practitioners by clarifying the link of systems thinking and modeling to everyday practice in public health
212	4	Apply systems thinking to physical and mental health problems affecting individuals, families, and communities throughout the human life cycle
201.18	5	Address issues of politics and bureaucracy that hinder systems thinking (e.g., politician's ignorance of how their systems work, public employee unions that avoid employee accountability, civil service systems that encourage stagnation, etc.)
178.189.61	6	Address people's fears about implementing systems approaches (e.g., job loss, too difficult, change)
61.298.173.307.107.223.226.224.148.106.	7	To address the personal and psychological barriers people may have to systems thinking
195	8	Develop instruments that measure and/or evaluate systems thinking/thinkers
242	9	A critical mass of practitioners who are able to approach public health from a non-linear perspective
54.292.280.126.286.40.155.293.88.16.89	10	Recognize the limitations of the dominant paradigm in public health (e.g., linear causality, reductionism, positivism, objectivism, the medical model, logic models, program-focused, disease-focused, frameworks)
54.292.280.126.286.40.155.293	11	Recognize the importance of a systems paradigm to public health (e.g., ecological, systemic, holistic, participatory, multi-dimensional, constructivist, adaptive, complex and nonlinear frameworks)
302	12	Move toward interventions based on syndemics

Phylogeny	Final Number	Randomized Sequence of Final Statements
44.214.215.2 88.67.293	13	Use participatory action approaches to partner with communities to co-define public health problems, challenges, needs, assets, and resources
182.154.134. 56.187.	14	Remove funding constraints that cause fragmentation of grant proposals or programs and confine health issues to narrow interpretations, actions and thinking
50.288	15	Develop a unified mission-vision across sectors (e.g., public health, education, public safety, behavioral health) and between layers (e.g., national, state, community) regarding the systems approach
267	16	Identify priority public health issues (tobacco, HIV, obesity...) as possible tipping points for early examples of systems thinking and modeling
8	17	Reward transformation of need for services rather than just growth of service delivery
30.17	18	Develop new systems-oriented approaches to data (e.g., more time series) and reporting (e.g., combine epidemiological data across disease/condition to encourage comparisons)
234	19	Increase funding for transdisciplinary and inter-agency collaborative projects with a systems focus
106	20	Address the notion that systems concepts are sometimes perceived as 'difficult' or 'too complex'
171	21	Avoid over-promising what systems thinking and modeling can currently deliver
278.249.314. 121	22	Develop an industry-wide sophisticated and user friendly infrastructure for systems (including networks, knowledge and data management, synthesis, interpretation and dissemination)
80.271.149.2 97.191.181.1 52.296.156	23	Change the tendency of public health departments to pander to the lowest consumer instincts (e.g., reactive, short-term paradigm)
102	24	Training and education in systems research techniques for public health professionals
42.59.311.22 2.105.243.	25	Engage all the different stakeholders in any given system

Phylogeny	Final Number	Randomized Sequence of Final Statements
145	26	Increase the efficacy of evaluation methods that provide continuous monitoring and assessment of progress in relation to stated objectives and specified time frames
32	27	Incorporate structural interventions such as law or policy into planning efforts
257.48	28	Multiple, geographically dispersed, Centers of Systems Thinking and Modeling excellence providing expert technical assistance
109	29	Train scientists in the facilitation skills that are needed to employ many systems approaches
295	30	Establish simple opportunities to 'get to know' people outside of one's traditional arena
156	31	Change from a deficit-based approach and language (e.g., disease prevention) to strength-based approach and language (e.g., achieving health)
40	32	Change the way data are reported to encourage and reinforce paradigm shifts toward systems modes of thinking
138	33	Public health and other government agencies are not jointly accountable to common performance goals
62.57.110.9.2 37.136.70.14. 142.229.264. 164.291.33.3 17.	34	Widespread technical training in systems approaches and analytic methods (e.g., operations research, complex programming, nonlinear and systems dynamics, statistical modeling, game-based approaches and simulations, etc.)
121.248.118. 117.	35	Effective, accessible and affordable tools for practitioner research
299.26	36	Encourage people and organizations to be open and non-territorial and to think in micro and macro organizational terms
153	37	Remove funding constraints that hinder systems approaches such as 'stove pipes' that cause managers to think in silos or categories
259.316.233. 258.168.100. 171.20.65.	38	Rigorous research that demonstrates the value of systems thinking, methods, approaches and research

Phylogeny	Final Number	Randomized Sequence of Final Statements
143	39	Development and incorporation of racial equity indicators in all aspects of public planning, implementation, and evaluation
28	40	Train public health leaders to manage and advocate for public health systems rather than programs
297.191.	41	Value studying parts in their natural environments rather than studying parts in isolation
157	42	Allow categorically funded program areas to pool funding in order to accomplish common goals
97.241.97.98. 36.3.186	43	Develop new evaluation approaches that will help demonstrate the value of systems approaches, such as Syndemics, in public health
49.5.111	44	Getting government and public health officials at state and federal levels to appreciate the value of community-based approaches and highlight citizenship and local governance in public health
58.209.288	45	Understanding of whether or not systems at different levels (e.g., organizational, community, regional, state, national) can be approached using the same or similar tools
76	46	Interactive learning opportunities for decision-makers in public health, so that they can learn to work effectively with systems scientists
127.47.217.2 16.257.76.	47	Forums that facilitate collaborative learning and knowledge sharing about systems thinking and methods
62.57.110.9.2 37.136.70.14. 142.229.264. 164.291.33.3 17.72	48	Develop a comprehensive 'encyclopedia' for systems thinking approaches, methodologies, and applications to public health that provides guidance and definitions on the scope and practice of systems research

Phylogeny	Final Number	Randomized Sequence of Final Statements
208.11.10.177.225.72.282.131.160.192.230.194.284.63.304.130.188.163.122.231.162.88.196.245.285.289.188.95.261.255.35.283.101.25.176.318.228106.2.275.128.	49	Develop curriculum modules on systems thinking that are accessible to a wide-variety of different skill sets and previous training
61	50	Determine why people make decisions not to use systems thinking or approaches
262	51	Show how systems thinking/modeling can suggest actions that would not have been taken otherwise
175.77	52	Encourage funding bodies to recognize and cover costs of collaboration for transdisciplinary teams working together on public health challenges
34.288	53	Have more community planning between State and Federal Health Departments for diseases like HIV, STI, mental illness, substance abuse, and violence
219.205.312	54	Develop new research, educational and technical partnerships with the private sector and with existing initiatives, centers, and institutes; especially those that specialize in systems-based approaches

Phylogeny	Final Number	Randomized Sequence of Final Statements
208.11.10.17 7.225.72.282. 131.160.192. 230.194.284. 63.304.130.1 88.163.122.2 31.162.88.19 6.245.285.28 9.188.95.261. 255.35.283.1 01.25.176.31 8.228106.2.2 75.128.62.57. 110.9.237.13 6.70.14.142.2 29.264.164.2 91.33.317.	55	Include both mathematical and conceptual education and training in systems thinking and methods for novice and advanced individuals
217	56	Distance learning courses, webinars, and other educational products and services about systems thinking and modeling
179	57	Jurisdictional ’authority‘ and power between federal (CDC/HRSA), city, county and state agencies discourage systems thinking
	58	Encourage participation and pragmatism in research of public health systems
159.247.238.	59	A common language for systems thinking in public health (e.g., a glossary)
90.260.69.	60	Increase research funding for exploratory research, projects and model development
52	61	Overcome the problem of focus on and loyalty to the goals and outcomes of employing organizations
119.235.	62	Sustain multi-disciplinary teams from a broad range of health and science backgrounds and thinking (e.g., deductive/inductive, research/practice)

Phylogeny	Final Number	Randomized Sequence of Final Statements
42.59.311.222.105.243.	63	Build 'mindshare' within the public health field through popular books, articles, and models
114	64	Publication of more systems thinking and modeling work in mainstream public health journals and public health web forums
93.221	65	Identify and enlist key political stakeholders
158	66	Encourage forums for sustained interaction between users (decision makers) and developers (analysts) of systems models
305	67	Question the boundaries of our traditional dichotomies: biological/social, physical/psychological, genetic/environmental, random/deterministic, choice/constraint (re: life styles), quantitative/qualitative (re: modeling)
216	68	International, national, regional, state, and local 'Learning Collaboratives' about systems thinking and modeling
60	69	One or more systems assessment tools that can be used by organizations, communities, regions, states and at the national level that demonstrates the mix of quantitative and qualitative evaluation methods and strategies can be used.
208.11.10.177.225.72.282.131.160.192.230.194.284.63.304.130.188.163.122.231.162.88.196.245.285.289.188.95.261.255.35.283.101.25.176.318.228106.2.275.128.	70	Develop and deliver a 'Systems Thinking 101' course for public health professionals
268.115.309.246.198.172.250.164.166.204	71	Identify and disseminate examples of 'best practices' or 'what works' in systems thinking inside and outside of public health

Phylogeny	Final Number	Randomized Sequence of Final Statements
208.11.10.17 7.225.72.282. 131.160.192. 230.194.284. 63.304.130.1 88.163.122.2 31.162.88.19 6.245.285.28 9.188.95.261. 255.35.283.1 01.25.176.31 8.228106.2.2 75.128.	72	Demonstrate the excitement and the potential of systems thinking through education and training that is accessible to anyone
272	73	Develop technology that facilitates public health from a systems perspective (e.g., sensors for preventative health support, on body/in home to monitor, diet, vital signs, hormone, sugar levels)
208.11.10.17 7.225.72.282. 131.160.192. 230.194.284. 63.304.130.1 88.163.122.2 31.162.88.19 6.245.285.28 9.188.95.261. 255.35.283.1 01.25.176.31 8.228106.2.2 75.128.104	74	Develop comprehensive education/training programs about systems thinking for practitioners, researchers, and communities that support learning about the language, vales and norms in other parts of the system
150	75	Reduce the overemphasis on immediate positive program impacts by taking a longer-term view
254.14	76	Reflective time for people and teams to think about systems

Phylogeny	Final Number	Randomized Sequence of Final Statements
298	77	Develop organizations in which learning is encouraged, being wrong is okay and taking risks is rewarded
315.112.	78	The traditional passive role that science has played in policy decision-making processes needs to be more active
197	79	Provide evidence to epidemiologists, politicians and the public health system, that the results of systems thinking models are not unduly sensitive to modelers' assumptions
281	80	Differentiating between analytic approaches that are data-based from those that are conceptual (e.g., simulations)
294.23.256.51.123.202.133.266	81	Provide incentives that encourage systems thinking
15	82	Anticipate the dynamic consequences of policies (e.g., potential for worse-before-better or better-before-worse, trade-offs against other values)
71.75.43.183.121.248.118.117.48	83	Develop a detailed website where researchers, policy makers and practitioners can access expertise and information about systems thinking and modeling in public health
210.135.165.74.82	84	Develop consistent (multi-year) funding streams that encourage long-term systemic research and programs
211	85	Connect systems thinking and modeling to the series of recent Institute of Medicine reports (e.g., bridging the quality chasm, reducing health care errors, eliminating health and health care disparities, etc.)
80.271.149.297.191.181.45.46	86	Recognize that many public health problems are complex and require long-term systems approaches
290	87	Reconcile the problem that historic data is often unavailable to calibrate or benchmark sophisticated models
99	88	Demote the primacy of the medical model applied to public health
18	89	Focus incentives on reducing summary measures of illness burden (e.g., reducing the number of unhealthy days)
206.124.218.	90	Incorporate training in systems thinking and modeling throughout entire educational system from elementary school through advanced graduate degrees

Phylogeny	Final Number	Randomized Sequence of Final Statements
306	91	Expand infectious disease work to include animal/plant disease and view parasitism as a universal phenomenon of ecology and evolution.
6	92	Set priorities by analyzing system-wide issues, rather than simply ranking by disease burden or attributable risk
151	93	Increased page limitations imposed by peer-reviewed journals that make it almost impossible to describe problems or solutions from a systems perspective, thereby limiting dissemination of systems-based thinking
116, 9, 117, 118, 291	94	Develop skills and become more comfortable in integrating simulation and modeling approaches into research
79.227.	95	Understand that systems thinking is a paradigm and that paradigm shifts require transformational learning rather than mere content learning
19.288	96	Remove the constraints and relax the boundaries that hinder the success of systems approaches
31.1	97	Complement the epidemic orientation (disease-based or risk factor-based) with a syndemic orientation (place-based and population-based)
300.141.190. 210	98	Identify and develop funding sources that will encourage systems approaches to public health
74	99	Develop funding for demonstration projects that validate systems approaches to public health
251.116.170. 58.87.66.60.2 20.37.209.68. 281.	100	Development of methods and tools that encourage systems approaches in research and evaluation

APPENDIX 6A: Statements by Bridging Values and Ratings (Descending)

#	Statement	Bridging Value	Rating
98	Identify and develop funding sources that will encourage systems approaches to public health	0.48	4.13
99	Develop funding for demonstration projects that validate systems approaches to public health	0.48	4.09
19	Increase funding for transdisciplinary and inter-agency collaborative projects with a systems focus	0.50	4.06
37	Remove funding constraints that hinder systems approaches such as ‘stove pipes’ that cause managers to think in silos or categories	0.38	4.06
84	Develop consistent (multi-year) funding streams that encourage long-term systemic research and programs	0.44	4.04
11	Recognize the importance of a systems paradigm to public health (e.g., ecological, systemic, holistic, participatory, multi-dimensional, constructivist, adaptive, complex and nonlinear frameworks)	0.32	4.00
52	Encourage funding bodies to recognize and cover costs of collaboration for transdisciplinary teams working together on public health challenges	0.40	3.96
71	Identify and disseminate examples of ‘best practices’ or ‘what works’ in systems thinking inside and outside of public health	0.28	3.93
100	Development of methods and tools that encourage systems approaches in research and evaluation	0.20	3.93
14	Remove funding constraints that cause fragmentation of grant proposals or programs and confine health issues to narrow interpretations, actions and thinking	0.43	3.91
43	Develop new evaluation approaches that will help demonstrate the value of systems approaches, such as Syndemics, in public health	0.35	3.78
38	Rigorous research that demonstrates the value of systems thinking, methods, approaches and research	0.18	3.76

#	Statement	Bridging Value	Rating
3	Encourage collaborations between researchers and practitioners by clarifying the link of systems thinking and modeling to everyday practice in public health	0.76	3.74
13	Use participatory action approaches to partner with communities to co-define public health problems, challenges, needs, assets, and resources	0.70	3.74
92	Set priorities by analyzing system-wide issues, rather than simply ranking by disease burden or attributable risk	0.28	3.74
1	Integrate organizational planning and evaluation functions around a systems approach	0.78	3.72
9	A critical mass of practitioners who are able to approach public health from a non-linear perspective	0.27	3.72
24	Training and education in systems research techniques for public health professionals	0.03	3.70
4	Apply systems thinking to physical and mental health problems affecting individuals, families, and communities throughout the human life cycle	1.00	3.65
62	Sustain multi-disciplinary teams from a broad range of health and science backgrounds and thinking (e.g., deductive/inductive, research/practice)	0.70	3.65
40	Train public health leaders to manage and advocate for public health systems rather than programs	0.27	3.63
42	Allow categorically funded program areas to pool funding in order to accomplish common goals	0.54	3.63
60	Increase research funding for exploratory research, projects and model development	0.46	3.63
85	Connect systems thinking and modeling to the series of recent Institute of Medicine reports (e.g., bridging the quality chasm, reducing health care errors, eliminating health and health care disparities, etc.)	0.33	3.63
49	Develop curriculum modules on systems thinking that are accessible to a wide-variety of different skill sets and previous training	0.01	3.61

#	Statement	Bridging Value	Rating
51	Show how systems thinking/modeling can suggest actions that would not have been taken otherwise	0.33	3.61
64	Publication of more systems thinking and modeling work in mainstream public health journals and public health web forums	0.36	3.59
10	Recognize the limitations of the dominant paradigm in public health (e.g., linear causality, reductionism, positivism, objectivism, the medical model, logic models, program-focused, disease-focused, frameworks)	0.42	3.57
81	Provide incentives that encourage systems thinking	0.40	3.56
44	Getting government and public health officials at state and federal levels to appreciate the value of community-based approaches and highlight citizenship and local governance in public health	0.48	3.54
75	Reduce the overemphasis on immediate positive program impacts by taking a longer-term view	0.27	3.54
15	Develop a unified mission-vision across sectors (e.g., public health, education, public safety, behavioral health) and between layers (e.g., national, state, community) regarding the systems approach	0.81	3.50
32	Change the way data are reported to encourage and reinforce paradigm shifts toward systems modes of thinking	0.21	3.50
54	Develop new research, educational and technical partnerships with the private sector and with existing initiatives, centers, and institutes; especially those that specialize in systems-based approaches	0.70	3.48
66	Encourage forums for sustained interaction between users (decision makers) and developers (analysts) of systems models	0.56	3.48
16	Identify priority public health issues (tobacco, HIV, obesity...) as possible tipping points for early examples of systems thinking and modeling	0.35	3.46
65	Identify and enlist key political stakeholders	0.69	3.46

#	Statement	Bridging Value	Rating
74	Develop comprehensive education/training programs about systems thinking for practitioners, researchers, and communities that support learning about the language, vales and norms in other parts of the system	0.05	3.46
86	Recognize that many public health problems are complex and require long-term systems approaches	0.39	3.46
70	Develop and deliver a 'Systems Thinking 101' course for public health professionals	0.03	3.44
83	Develop a detailed website where researchers, policy makers and practitioners can access expertise and information about systems thinking and modeling in public health	0.24	3.44
97	Complement the epidemic orientation (disease-based or risk factor-based) with a syndemic orientation (place-based and population-based)	0.30	3.44
8	Develop instruments that measure and/or evaluate systems thinking/thinkers	0.46	3.43
35	Effective, accessible and affordable tools for practitioner research	0.32	3.43
18	Develop new systems-oriented approaches to data (e.g., more time series) and reporting (e.g., combine epidemiological data across disease/condition to encourage comparisons)	0.21	3.39
25	Engage all the different stakeholders in any given system	0.85	3.37
5	Address issues of politics and bureaucracy that hinder systems thinking (e.g., politician's ignorance of how their systems work, public employee unions that avoid employee accountability, civil service systems that encourage stagnation, etc.)	0.42	3.35
41	Value studying parts in their natural environments rather than studying parts in isolation	0.31	3.35
26	Increase the efficacy of evaluation methods that provide continuous monitoring and assessment of progress in relation to stated objectives and specified time frames	0.52	3.33
47	Forums that facilitate collaborative learning and knowledge sharing about systems thinking and methods	0.24	3.33

#	Statement	Bridging Value	Rating
69	One or more systems assessment tools that can be used by organizations, communities, regions, states and at the national level that demonstrates the mix of quantitative and qualitative evaluation methods and strategies can be used.	0.30	3.33
96	Remove the constraints and relax the boundaries that hinder the success of systems approaches	0.39	3.33
34	Widespread technical training in systems approaches and analytic methods (e.g., operations research, complex programming, nonlinear and systems dynamics, statistical modeling, game-based approaches and simulations, etc.)	0.05	3.31
95	Understand that systems thinking is a paradigm and that paradigm shifts require transformational learning rather than mere content learning	0.35	3.31
28	Multiple, geographically dispersed, Centers of Systems Thinking and Modeling excellence providing expert technical assistance	0.26	3.28
22	Develop an industry-wide sophisticated and user friendly infrastructure for systems (including networks, knowledge and data management, synthesis, interpretation and dissemination)	0.44	3.28
29	Train scientists in the facilitation skills that are needed to employ many systems approaches	0.07	3.28
46	Interactive learning opportunities for decision-makers in public health, so that they can learn to work effectively with systems scientists	0.22	3.28
58	Encourage participation and pragmatism in research of public health systems	0.24	3.28
77	Develop organizations in which learning is encouraged, being wrong is okay and taking risks is rewarded	0.35	3.28
56	Distance learning courses, webinars, and other educational products and services about systems thinking and modeling	0.00	3.26
68	International, national, regional, state, and local ‘Learning Collaboratives’ about systems thinking and modeling	0.30	3.26

#	Statement	Bridging Value	Rating
90	Incorporate training in systems thinking and modeling throughout entire educational system from elementary school through advanced graduate degrees	0.12	3.24
72	Demonstrate the excitement and the potential of systems thinking through education and training that is accessible to anyone	0.15	3.22
82	Anticipate the dynamic consequences of policies (e.g., potential for worse-before-better or better-before-worse, trade-offs against other values)	0.55	3.22
59	A common language for systems thinking in public health (e.g., a glossary)	0.16	3.19
12	Move toward interventions based on syndemics	0.61	3.17
21	Avoid over-promising what systems thinking and modeling can currently deliver	0.47	3.17
27	Incorporate structural interventions such as law or policy into planning efforts	0.73	3.17
36	Encourage people and organizations to be open and non-territorial and to think in micro and macro organizational terms	0.72	3.17
48	Develop a comprehensive 'encyclopedia' for systems thinking approaches, methodologies, and applications to public health that provides guidance and definitions on the scope and practice of systems research	0.14	3.15
63	Build 'mindshare' within the public health field through popular books, articles, and models	0.28	3.13
6	Address people's fears about implementing systems approaches (e.g., job loss, too difficult, change)	0.53	3.11
7	To address the personal and psychological barriers people may have to systems thinking	0.68	3.11
33	Public health and other government agencies are not jointly accountable to common performance goals	0.51	3.11
55	Include both mathematical and conceptual education and training in systems thinking and methods for novice and advanced individuals	0.04	3.11

#	Statement	Bridging Value	Rating
30	Establish simple opportunities to 'get to know' people outside of one's traditional arena	0.57	3.09
67	Question the boundaries of our traditional dichotomies: biological/social, physical/psychological, genetic/environmental, random/deterministic, choice/constraint (re: life styles), quantitative/qualitative (re: modeling)	0.32	3.09
94	Develop skills and become more comfortable in integrating simulation and modeling approaches into research	0.14	3.09
78	The traditional passive role that science has played in policy decision-making processes needs to be more active	0.41	3.06
31	Change from a deficit-based approach and language (e.g., disease prevention) to strength-based approach and language (e.g., achieving health)	0.44	3.06
45	Understanding of whether or not systems at different levels (e.g., organizational, community, regional, state, national) can be approached using the same or similar tools	0.35	3.04
53	Have more community planning between State and Federal Health Departments for diseases like HIV, STI, mental illness, substance abuse, and violence	0.97	3.04
88	Demote the primacy of the medical model applied to public health	0.39	3.02
23	Change the tendency of public health departments to pander to the lowest consumer instincts (e.g., reactive, short-term paradigm)	0.31	2.98
17	Reward transformation of need for services rather than just growth of service delivery	0.35	2.96
79	Provide evidence to epidemiologists, politicians and the public health system, that the results of systems thinking models are not unduly sensitive to modelers' assumptions	0.23	2.94
50	Determine why people make decisions not to use systems thinking or approaches	0.59	2.91

#	Statement	Bridging Value	Rating
73	Develop technology that facilitates public health from a systems perspective (e.g., sensors for preventative health support, on body/in home to monitor, diet, vital signs, hormone, sugar levels)	0.30	2.89
57	Jurisdictional ’authority‘ and power between federal (CDC/HRSA), city, county and state agencies discourage systems thinking	0.46	2.83
89	Focus incentives on reducing summary measures of illness burden (e.g., reducing the number of unhealthy days)	0.27	2.83
2	Demote the primacy of the current model for academic advancement (e.g., publish narrowly or perish)	0.52	2.81
20	Address the notion that systems concepts are sometimes perceived as ‘difficult’ or ‘too complex’	0.63	2.81
76	Reflective time for people and teams to think about systems	0.36	2.81
39	Development and incorporation of racial equity indicators in all aspects of public planning, implementation, and evaluation	0.42	2.80
61	Overcome the problem of focus on and loyalty to the goals and outcomes of employing organizations	0.38	2.65
87	Reconcile the problem that historic data is often unavailable to calibrate or benchmark sophisticated models	0.24	2.65
80	Differentiating between analytic approaches that are data-based from those that are conceptual (e.g., simulations)	0.23	2.41
93	Increased page limitations imposed by peer-reviewed journals that make it almost impossible to describe problems or solutions from a systems perspective, thereby limiting dissemination of systems-based thinking	0.50	2.41
91	Expand infectious disease work to include animal/plant disease and view parasitism as a universal phenomenon of ecology and evolution.	0.69	2.30

Concept System Exercise:
Selecting the Number of Clusters

In this exercise you will select the final number of clusters for the Strategic Planning example. To do this, print a 20-cluster solution. Then draw cluster replay maps from 20 to 8 clusters and record the cluster merges. Finally, redraw the merges (using the worksheet that we've given you) and make a decision on the final number of clusters.

1. Save a 20-cluster map.

1. As Admin, open the Strategic Planning example.
2. Click on the ***Concept Map*** button.
3. Select the ***Map Settings*** tab.
4. In the cluster map section, choose "Cluster Map" from the list box.
5. Set the number of clusters to 20.
6. Click the ***Draw Map*** button.
7. Choose ***Maps*** ⇒ ***Save Map*** menu.
8. Exit draw maps.

2. Print the 20-cluster solution.

1. Select the ***File*** ⇒ ***Open Reports*** menu.
2. Under the "Statement Tables and Lists" report type, select "Cluster Bridgings".
3. Click the ***View Report*** button.
4. In the print preview window, you will see the 20-cluster solution with bridging values.
5. Close the preview window. (This report is in your binder following this exercise.)
6. Exit the print window.

3. Do cluster replay.

1. Click the ***Concept Map*** button.
2. Select the ***Map Settings*** tab.
3. In the "Point Map" section, set map to *None*.
4. In the Cluster Map section select "Cluster Replay Map".
5. In the Number of Clusters box type 20.
6. In the Cluster Replay section, specify from 20 to 8.
7. Click the "Draw Map" button. The replay may take some time to complete.
8. Note the results printed in the text box below the map. It should look like this:

Cluster Replay From 20 To 8 Done

Cluster Replay Listing
At Cluster 19 merged: 5 6
At Cluster 18 merged: 16 17
At Cluster 17 merged: 14 15
At Cluster 16 merged: 9 10
At Cluster 15 merged: 5 6 7
At Cluster 14 merged: 12 13
At Cluster 13 merged: 1 2
At Cluster 12 merged: 11 12 13
At Cluster 11 merged: 18 19
At Cluster 10 merged: 1 2 3
At Cluster 9 merged: 8 9 10
At Cluster 8 merged: 14 15 16 17

You will use this information in Step 4 below.

4. Select the final number of clusters.

To do this step, you will need to use the Worksheet for Selecting the Number of Clusters and the 20 cluster printout that are supplied following these instructions.

1. In the first column of the worksheet labeled "Cluster Number", write the numbers from 19 to 8 in descending order.
2. In the next column of the worksheet labeled "Clusters Merged", copy the numbers of the clusters merged as shown in the textbox at the bottom of the map (or shown above on this page). For instance, in the first row (for 19 clusters) you would enter 5 & 6.
3. Now, begin with the top row of the worksheet and, *for each line*, do the following steps:
4.

   a) identify which clusters are merged at this step

   b) read through the statements for those clusters on the cluster listing

   c) decide whether you Agree that those clusters should be merged, Disagree, or are Undecided and check the appropriate box. Feel free to add any comments about your decision in the last column

5. When you've completed the worksheet (from the 19 to 8 cluster solutions), inspect your Assessment column from top to bottom. You should see that near the top (higher-cluster solutions) you generally will have more Agrees and at the bottom, you will have more Disagrees checked. In the middle you will most likely have a variety of all three. Look for the point at which the Agrees turned into Disagrees. *You want to select as your final cluster solution, the lowest one on which you consistently agreed.* (Sometimes you will have a string of Agrees, followed by some Undecideds, and then another Agree. Generally, you should consider that later Agree spurious). If you are in doubt about how many clusters to select, *err on the side of more rather than fewer*.

5. Save the Map
1. If you have been following correctly, you should still have the cluster replay map on the screen. Click on the ***Settings*** button. 2. Select the ***Select Ratings*** tab. 3. Select the CM Importance rating. 4. Select only the following users: Bill, Bob, Carol, Don, Ed, John, Laura, Marty, Mary and Pat (this should be all of the available users for this rating). 5. Select the ***Map Settings*** tab. 6. Select "Point Rating Map". 7. Select "Cluster Map". 8. Set "Number of Clusters" to the final number you decided on in Step 4 above. 9. Click on "Draw Map". 10. Select the ***Maps*** ⇒ ***Save Map*** menu. 11. Exit draw maps. 12. Exit the Concept System.

Selecting the Number of Clusters Worksheet

Cluster Number	Clusters Merged	Assessment	Comments
19	8,9	□ Agree □ Undecided □ Disagree	
18	19,20	□ Agree □ Undecided □ Disagree	
17	5,6	□ Agree □ Undecided □ Disagree	
16	1,2	□ Agree □ Undecided □ Disagree	
15	15,16	□ Agree □ Undecided □ Disagree	
14	10,11	□ Agree □ Undecided □ Disagree	
13	3,4	□ Agree □ Undecided □ Disagree	
12	13,14	□ Agree □ Undecided □ Disagree	
11	15,16,17	□ Agree □ Undecided □ Disagree	
10	5,6,7	□ Agree □ Undecided □ Disagree	
9	10,11,12	□ Agree □ Undecided □ Disagree	
8	5,6,7,8,9	□ Agree □ Undecided □ Disagree	

APPENDIX 6C: Statements by Cluster and Average Ratings

		Avg. Rating
Cluster: Expand Cross-Category Funding		
98	Identify and develop funding sources that will encourage systems approaches to public health	4.13
99	Develop funding for demonstration projects that validate systems approaches to public health	4.09
37	Remove funding constraints that hinder systems approaches such as ‘stove pipes’ that cause managers to think in silos or categories	4.06
19	Increase funding for transdisciplinary and inter-agency collaborative projects with a systems focus	4.06
84	Develop consistent (multi-year) funding streams that encourage long-term systemic research and programs	4.04
52	Encourage funding bodies to recognize and cover costs of collaboration for transdisciplinary teams working together on public health challenges	3.96
14	Remove funding constraints that cause fragmentation of grant proposals or programs and confine health issues to narrow interpretations, actions and thinking	3.91
60	Increase research funding for exploratory research, projects and model development	3.63
42	Allow categorically funded program areas to pool funding in order to accomplish common goals	3.63
33	Public health and other government agencies are not jointly accountable to common performance goals	3.11
	Cluster Avg.	3.86

		Avg. Rating
Cluster: Support Dynamic & Diverse Networks		
3	Encourage collaborations between researchers and practitioners by clarifying the link of systems thinking and modeling to everyday practice in public health	3.74
13	Use participatory action approaches to partner with communities to co-define public health problems, challenges, needs, assets, and resources	3.74
62	Sustain multi-disciplinary teams from a broad range of health and science backgrounds and thinking (e.g., deductive/inductive, research/practice)	3.65
66	Encourage forums for sustained interaction between users (decision makers) and developers (analysts) of systems models	3.48
54	Develop new research, educational and technical partnerships with the private sector and with existing initiatives, centers, and institutes; especially those that specialize in systems-based approaches	3.48
35	Effective, accessible and affordable tools for practitioner research	3.43
25	Engage all the different stakeholders in any given system	3.37
30	Establish simple opportunities to 'get to know' people outside of one's traditional arena	3.09
	Cluster Avg.	3.50

		Avg. Rating
Cluster: Use Systems Measures & Models		
100	Development of methods and tools that encourage systems approaches in research and evaluation	3.93
43	Develop new evaluation approaches that will help demonstrate the value of systems approaches, such as Syndemics, in public health	3.78
16	Identify priority public health issues (tobacco, HIV, obesity...) as possible tipping points for early examples of systems thinking and modeling	3.46
8	Develop instruments that measure and/or evaluate systems thinking/thinkers	3.43
18	Develop new systems-oriented approaches to data (e.g., more time series) and reporting (e.g., combine epidemiological data across disease/condition to encourage comparisons)	3.39
69	One or more systems assessment tools that can be used by organizations, communities, regions, states and at the national level that demonstrates the mix of quantitative and qualitative evaluation methods and strategies can be used.	3.33
26	Increase the efficacy of evaluation methods that provide continuous monitoring and assessment of progress in relation to stated objectives and specified time frames	3.33
22	Develop an industry-wide sophisticated and user friendly infrastructure for systems (including networks, knowledge and data management, synthesis, interpretation and dissemination)	3.28
45	Understanding of whether or not systems at different levels (e.g., organizational, community, regional, state, national) can be approached using the same or similar tools	3.04
73	Develop technology that facilitates public health from a systems perspective (e.g., sensors for preventative health support, on body/in home to monitor, diet, vital signs, hormone, sugar levels)	2.89
	Cluster Avg.	3.39

		Avg. Rating
Cluster: Inspire Integrative Learning		
71	Identify and disseminate examples of ‘best practices’ or ‘what works’ in systems thinking inside and outside of public health	3.93
9	A critical mass of practitioners who are able to approach public health from a non-linear perspective	3.72
24	Training and education in systems research techniques for public health professionals	3.70
40	Train public health leaders to manage and advocate for public health systems rather than programs	3.63
49	Develop curriculum modules on systems thinking that are accessible to a wide-variety of different skill sets and previous training	3.61
64	Publication of more systems thinking and modeling work in mainstream public health journals and public health web forums	3.59
74	Develop comprehensive education/training programs about systems thinking for practitioners, researchers, and communities that support learning about the language, vales and norms in other parts of the system	3.46
70	Develop and deliver a ‘Systems Thinking 101’ course for public health professionals	3.44
83	Develop a detailed website where researchers, policy makers and practitioners can access expertise and information about systems thinking and modeling in public health	3.44
47	Forums that facilitate collaborative learning and knowledge sharing about systems thinking and methods	3.33
34	Widespread technical training in systems approaches and analytic methods (e.g., operations research, complex programming, nonlinear and systems dynamics, statistical modeling, game-based approaches and simulations, etc.)	3.31
28	Multiple, geographically dispersed, Centers of Systems Thinking and Modeling excellence providing expert technical assistance	3.28

		Avg. Rating
Cluster: Inspire Integrative Learning (continued)		
46	Interactive learning opportunities for decision-makers in public health, so that they can learn to work effectively with systems scientists	3.28
29	Train scientists in the facilitation skills that are needed to employ many systems approaches	3.28
68	International, national, regional, state, and local 'Learning Collaboratives' about systems thinking and modeling	3.26
56	Distance learning courses, webinars, and other educational products and services about systems thinking and modeling	3.26
90	Incorporate training in systems thinking and modeling throughout entire educational system from elementary school through advanced graduate degrees	3.24
72	Demonstrate the excitement and the potential of systems thinking through education and training that is accessible to anyone	3.22
59	A common language for systems thinking in public health (e.g., a glossary)	3.19
48	Develop a comprehensive 'encyclopedia' for systems thinking approaches, methodologies, and applications to public health that provides guidance and definitions on the scope and practice of systems research	3.15
63	Build 'mindshare' within the public health field through popular books, articles, and models	3.13
55	Include both mathematical and conceptual education and training in systems thinking and methods for novice and advanced individuals	3.11
94	Develop skills and become more comfortable in integrating simulation and modeling approaches into research	3.09
	Cluster Avg.	3.38

		Avg. Rating
Cluster: Foster Systems Planning & Evaluation		
1	Integrate organizational planning and evaluation functions around a systems approach	3.72
4	Apply systems thinking to physical and mental health problems affecting individuals, families, and communities throughout the human life cycle	3.65
15	Develop a unified mission-vision across sectors (e.g., public health, education, public safety, behavioral health) and between layers (e.g., national, state, community) regarding the systems approach	3.50
65	Identify and enlist key political stakeholders	3.46
82	Anticipate the dynamic consequences of policies (e.g., potential for worse-before-better or better-before-worse, trade-offs against other values)	3.22
27	Incorporate structural interventions such as law or policy into planning efforts	3.17
12	Move toward interventions based on syndemics	3.17
53	Have more community planning between State and Federal Health Departments for diseases like HIV, STI, mental illness, substance abuse, and violence	3.04
39	Development and incorporation of racial equity indicators in all aspects of public planning, implementation, and evaluation	2.80
	Cluster Avg.	3.30

		Avg. Rating
Cluster: Show Potential of Systems Approaches		
38	Rigorous research that demonstrates the value of systems thinking, methods, approaches and research	3.76
92	Set priorities by analyzing system-wide issues, rather than simply ranking by disease burden or attributable risk	3.74
85	Connect systems thinking and modeling to the series of recent Institute of Medicine reports (e.g., bridging the quality chasm, reducing health care errors, eliminating health and health care disparities, etc.)	3.63
51	Show how systems thinking/modeling can suggest actions that would not have been taken otherwise	3.61
32	Change the way data are reported to encourage and reinforce paradigm shifts toward systems modes of thinking	3.50
97	Complement the epidemic orientation (disease-based or risk factor-based) with a syndemic orientation (place-based and population-based)	3.44
58	Encourage participation and pragmatism in research of public health systems	3.28
79	Provide evidence to epidemiologists, politicians and the public health system, that the results of systems thinking models are not unduly sensitive to modelers' assumptions	2.94
76	Reflective time for people and teams to think about systems	2.81
87	Reconcile the problem that historic data is often unavailable to calibrate or benchmark sophisticated models	2.65
80	Differentiating between analytic approaches that are data-based from those that are conceptual (e.g., simulations)	2.41
	Cluster Avg.	3.25

		Avg. Rating
Cluster: Explore Systems Paradigms & Perspectives		
11	Recognize the importance of a systems paradigm to public health (e.g., ecological, systemic, holistic, participatory, multi-dimensional, constructivist, adaptive, complex and nonlinear frameworks)	4.00
10	Recognize the limitations of the dominant paradigm in public health (e.g., linear causality, reductionism, positivism, objectivism, the medical model, logic models, program-focused, disease-focused, frameworks)	3.57
44	Getting government and public health officials at state and federal levels to appreciate the value of community-based approaches and highlight citizenship and local governance in public health	3.54
86	Recognize that many public health problems are complex and require long-term systems approaches	3.46
41	Value studying parts in their natural environments rather than studying parts in isolation	3.35
95	Understand that systems thinking is a paradigm and that paradigm shifts require transformational learning rather than mere content learning	3.31
36	Encourage people and organizations to be open and non-territorial and to think in micro and macro organizational terms	3.17
21	Avoid over-promising what systems thinking and modeling can currently deliver	3.17
7	To address the personal and psychological barriers people may have to systems thinking	3.11
67	Question the boundaries of our traditional dichotomies: biological/social, physical/psychological, genetic/environmental, random/deterministic, choice/constraint (re: life styles), quantitative/qualitative (re: modeling)	3.09
31	Change from a deficit-based approach and language (e.g., disease prevention) to strength-based approach and language (e.g., achieving health)	3.06
88	Demote the primacy of the medical model applied to public health	3.02

		Avg. Rating
Cluster: Explore Systems Paradigms & Perspectives (continued)		
50	Determine why people make decisions not to use systems thinking or approaches	2.91
20	Address the notion that systems concepts are sometimes perceived as 'difficult' or 'too complex'	2.81
91	Expand infectious disease work to include animal/plant disease and view parasitism as a universal phenomenon of ecology and evolution.	2.30
	Cluster Avg.	3.19
Cluster: Utilize System Incentives		
81	Provide incentives that encourage systems thinking	3.56
75	Reduce the overemphasis on immediate positive program impacts by taking a longer-term view	3.54
5	Address issues of politics and bureaucracy that hinder systems thinking (e.g., politician's ignorance of how their systems work, public employee unions that avoid employee accountability, civil service systems that encourage stagnation, etc.)	3.35
96	Remove the constraints and relax the boundaries that hinder the success of systems approaches	3.33
77	Develop organizations in which learning is encouraged, being wrong is okay and taking risks is rewarded	3.28
6	Address people's fears about implementing systems approaches (e.g., job loss, too difficult, change)	3.11
78	The traditional passive role that science has played in policy decision-making processes needs to be more active	3.06
23	Change the tendency of public health departments to pander to the lowest consumer instincts (e.g., reactive, short-term paradigm)	2.98

		Avg. Rating
Cluster: Utilize System Incentives (continued)		
17	Reward transformation of need for services rather than just growth of service delivery	2.96
57	Jurisdictional ’authority‘ and power between federal (CDC/HRSA), city, county and state agencies discourage systems thinking	2.83
89	Focus incentives on reducing summary measures of illness burden (e.g., reducing the number of unhealthy days)	2.83
2	Demote the primacy of the current model for academic advancement (e.g., publish narrowly or perish)	2.81
61	Overcome the problem of focus on and loyalty to the goals and outcomes of employing organizations	2.65
93	Increased page limitations imposed by peer-reviewed journals that make it almost impossible to describe problems or solutions from a systems perspective, thereby limiting dissemination of systems-based thinking	2.41
	Cluster Avg.	3.05

REFERENCES

1. Chopra D. The Crisis of Perception. This is a website with a film clip on it of Deepak Chopra. Available at: http://www.big-picture.tv/index.php?id=53&cat=&a=119 Accessed February 1, 2006.

2. Capra F. The Crisis Of Perception. *Futurist.* Jan-Feb 1990;24(1):64-64.

3. Capra F. *The Web of Life*. London: HarperCollins; 1996.

4. Harris M. Part 3: Crisis of Perception [VHS]. Mystic Fire Video, 1992.

5. Senge PM. A Crisis of Perception. *The Systems Thinker.* December/January 1992-1993;3(10):1-3.

6. Starcke W. *The Third Appearance - A Crisis of perception*. Boerne, TX: Guadalupe Press; 2004.

7. *Crisis of perception* [videorecording /]. Amsterdam & New York: Art-of-Peace Foundation, Mystic Fire Video Inc. & Asset Foundation; 1992.

8. Darwin C, Barrett PH, Gautrey PJ, Herbert S, Kohn D, Smith S. *Charles Darwin's notebooks, 1836-1844 : geology, transmutation of species, metaphysical enquiries*. [London] Ithaca, N.Y.: British Museum (Natural History) ; Cornell University Press; 1987.

9. Dobzhansky T. Nothing in Biology Makes Sense Except in the Light of Evolution. *The American Biology Teacher.* 1973;March(35):125-129.

10. Boote DN, Beile P. Scholars Before Researchers: On the Centrality of the Dissertation Literature review in Research Preparation. *Educational Researcher.* 2005;34(6):3-15.

11. Hart C. *Doing a Literature Review: Releasing the Social Science Research Imagination*. London: Sage Publications; 1998.

12. Bertalanffy Lv. *General System Theory; Foundations, Development, Applications*. New York: G. Braziller; 1968.

13. Trochim WM, Cabrera DA, Milstein B, Gallagher RS, Leischow SJ. Practical Challenges of Systems Thinking and Modeling in Public Health *American Journal of Public Health.* March 2006 2006;96(3):1-9.

14. Laozi, Feng G-f, English J. *Tao Te Ching*. 1st ed. New York: Knopf; 1972.

15. Capra F. *The Tao of Physics: An Exploration of the Parallels Between Modern Physics and Eastern Mysticism*. 4th ed. Boston: Shambhala; 2000.

16. Midgley G, ed. *Systems Thinking, Volume I: General Systems Theory, Cybernetics and Complexity*. London: Sage Publications; 2003; No. 1.

17. Midgley G, ed. *Systems Thinking, Volume II: Systems Theories and Modelling*. London: Sage Publications; 2003; No. 2.

18. Midgley G, ed. *Systems Thinking, Volume IV: Critical Systems Thinking and Systemic Perspectives on Ethics, Power and Pluralism*. London: Sage Publications; 2003.

19. Midgley G, ed. *Systems Thinking, Volume III: Second Order Cybernetics, Systemic Therapy and Soft Systems Thinking*. London: Sage Publications; 2003.

20. Francois C. *International Encyclopedia Of Systems And Cybernetics*. 2nd edition ed. Munchen: K G Saur North Amer Research; 2004.

21. Schwarz E. Streams of Systemic Thought. May 2001 ed. Neuchâtel, Switzerland; 1996.

22. Watkins B. Modeling the Firm as a Network *Santa Fe Institute Working Paper Series.* 1998;98-06-055.

23. Labra FA, Abades SR, Marquet PA. Scaling Patterns in Exotic and Native Bird Species Distribution and Abundance *Santa Fe Institute Working Paper Series.* 2005;2005-05-019.

24. Newman MEJ. The structure and function of complex networks. *arXiv.* 25 March 2003 2003;1.

25. Jost J. Formal Aspects of the Emergence of Institutions *Santa Fe Institute Working Paper Series.* 2005;2005-05-018.

26. Barabási A-L, Bonabeau E. Scale-Free Networks. 2003;60-69(May).

27. Helbing D, Schonhof M, Stark H-U, Holyst JA. How Individuals Learn to Take Turns: Emergence of Alternating Cooperation in a Congestion Game and the Prisoner's Dilemma *Santa Fe Institute Working Paper Series.* 2005;2005-04-006.

28. Betty M. Predicting where we walk. *Nature.* July 3, 1997 1997;388.

29. Bettencourt LMA, Cintron-Arias A, Kaiser DI, Castillo-Chavez C. The Power of a Good Idea: Quantitative Modeling of the Spread of Ideas from Epidemiological Models *Santa Fe Institute Working Paper Series.* 2005;2005-02-002.

30. Tsallis C, Gell-Mann M, Sato Y. Special Scale-Invariant Occupancy of Phase Space Makes Entropy Sq Additive *Santa Fe Institute Working Paper Series.* 2005;2005-03-005.

31. Padgett JF, McLean PD. Elite Transformation and Organizational Invention in Renaissance Florence *Santa Fe Institute Working Paper Series.* 2005;2005-02-001.

32. Bertalanffy Lv. *General Systems Theory: Foundations, Development, Applications*. Revised Edition ed. New York: George Braziller; 2003.

33. Capra F. *The Hidden Connections: Integrating the Hidden Connections Among the Biological, Cognitive, and Social Dimensions of Life*. 1st ed. New York: Doubleday; 2002.

34. *Sustainable communities a management challenge* [sound recording]. Cambridge, Mass.: Pegasus Communications Inc.; 1994.

35. Capra F. *The Web of Life: a New Scientific Understanding of Living Systems*. 1st Anchor Books trade paperback ed. New York, N.Y.: Anchor Books; 1997.

36. Capra F. *The Turning Point: Science, Society, and the Rising Culture*. 8th impression. ed. London: Fontana; 1990.

37. *Mindwalk* [videorecording /]. Hollywood, Calif.: Paramount; 1992.

38. Wheatley MJ. *Leadership and the New Science: Learning About Organization from an Orderly Universe*. 1st ed. San Francisco: Berrett-Koehler Publishers; 1992.

39. Wheatley MJ. *Leadership and the new science: discovering order in a chaotic world*. 2nd ed. San Francisco: Berrett-Koehler Publishers; 1999.

40. Sweeney LB. *When a butterfly sneezes: a guide for helping kids explore interconnections in our world through favorite stories*. Waltham, MA: Pegasus Communications; 2001.

41. Seuss. *The butter battle book*. New York: Random House; 1984.

42. Gladwell M. *The tipping point : how little things can make a big difference*. 1st ed. Boston: Little, Brown; 2000.

43. Senge P. *The Fifth Discipline: The Art and Practice of The Learning Organization*. New York, NY: Currency Doubleday; 1990.

44. Senge P. *The Fifth Discipline*. New York: Currency; 1994.

45. Senge P, Renesch JE, Allee V. *Elegant solutions : the power of systems thinking*. Pleasanton, CA: New Leaders Press; 1999.

46. Senge PM, Scharmer CO, Jaworski J, Flowers BS. *Presence: Exploring Profound Change in People, Organizations, and Society*. New York: Currency Doubleday; 2005.

47. Senge PM, Sterman JD. Systems Thinking And Organizational Learning - Acting Locally And Thinking Globally In The Organization Of The Future. *European Journal Of Operational Research.* May 26 1992;59(1):137-150.

48. Waldrop MM. *Complexity: the emerging science at the edge of order and chaos*. New York: Simon & Schuster; 1992.

49. Strogatz SH. *Sync : the emerging science of spontaneous order*. 1st ed. New York: Hyperion; 2003.

50. Watts DJ. *Small worlds : the dynamics of networks between order and randomness*. Princeton, N.J.: Princeton University Press; 1999.

51. Watts DJ. *Six degrees : the science of a connected age*. 1st ed. New York: Norton; 2003.

52. Laszlo E. *The Systems View of the World: A Holistic Vision for Our Time (Advances in Systems Theory, Complexity, and the Human Sciences)*: Hampton Press; 1996.

53. Cope KL, Ahrens R. *Talking forward, talking back : critical dialogues with the Enlightenment*. New York: AMS Press; 2002.

54. Gell-Mann M. *Macrocosm and microcosm : space observations and the laws of nature*; 1972.

55. Gell-Mann M. The Concept of the Institute. In: Pines D, ed. *Emerging syntheses in science : proceedings of the founding workshops of the Santa Fe Institute, Santa Fe, New Mexico*. Redwood City, Calif.: Addison-Wesley; 1988.

56. Gell-Mann M. *Visions of a sustainable world*. Lincoln, Nebr.: University of Nebraska Foundation; 1992.

57. Gell-Mann M. Let's Call It Plectics. *Complexity.* 1995;1(5).

58. Gell-Mann M. What Is Complexity. *Complexity.* 1995;1(1).

59. Gell-Mann M. *The Quark and the Jaguar*. New York: W.H. Freeman and Co.; 1995.

60. Gell-Mann M. *The quark and the jaguar : adventures in the simple and the complex*. London: Abacus; 2003.

61. *From simplicity to complexity a discussion of the connection between the basic laws of physics and the complexity and diversity of the natural world* [sound recording]. Bethesda, Md.: National Institutes of Health; 1996.

62. Gell-Mann M, Ne'eman Y. *The eightfold way : with new contributions from the authors*. 1st Perseus Pub. ed. Cambridge, Mass.: Advanced Book Program Perseus Pub.; 2000.

63. Strogatz SH. *Nonlinear dynamics and Chaos : with applications to physics, biology, chemistry, and engineering*. Reading, Mass.: Addison-Wesley Pub.; 1994.

64. Strogatz SH. Exploring Complex Networks. *Nature.* March 8, 2001 2001;410(March):268-276.

65. Strogatz ST. The real scientific hero of 1953. *The New York Times.* March 4, 2003.

66. Bertalanffy Lv. *Organismic psychology and systems theory*. [Worcester, Mass.]: Clark University Press; 1968.

67. Bertalanffy Lv. The History and Status of General Systems Theory. In: Klir GJ, ed. *Trends in General Systems Theory*. New York: Wiley-Interscience; 1972:407-426.

68. Bertalanffy Lv, LaViolette PA. *A systems view of man*. Boulder, Colo.: Westview Press; 1981.

69. Bertalanffy Lv, Woodger JH. *Modern theories of development; an introduction to theoretical biology*. London: Oxford university press; 1933.

70. *The turning point a transformative vision for an ecological age* [sound recording]. Emeryville, CA: Enhanced Audio Systems; 1991.

71. *Characteristics of systems thinking* [sound recording /]. Big Sur, CA: Dolphin Tapes; 1995.

72. Capra F. The Web of Life. *Schrödinger Lecture* [http://www.wikinator.com/middleway/files/Capra97.pdf http://www2.tcd.ie/Physics/Schrodinger/Lecture3.html Accessed February 14, 2006.

73. Capra F. *The web of life : a new synthesis of mind and matter*. London: Flamingo; 1997.

74. Capra F. Ecology, Systems Thinking and Project-Based Learning. Paper presented at: Autodesk Sixth Annual Conference on Project-Based Learning, 1998; San Francisco.

75. Gleick J. *Chaos : making a new science*. New York, N.Y.: Penguin; 1988.

76. Krygiel AJ. *Behind the wizard's curtain: An integration environment for a system of systems*. Washington, DC: National Defense University; 1999.

77. Bronfenbrenner U. *Influences on human development*. Hinsdale, Ill.,: Dryden Press; 1972.

78. Bronfenbrenner U. *The ecology of human development : experiments by nature and design*. Cambridge, Mass.: Harvard University Press; 1979.

79. Forrester JW. *Industrial Dynamics*. Cambridge, MA: MIT Press; 1961.

80. Forrester JW. *Urban dynamics*. Cambridge, MA: MIT Press; 1969.

81. Forrester JW. Counterintuitive behavior of social systems. *Technology Review.* 1971;73(3):53-68.

82. Forrester JW. *World dynamics*. Cambridge, Mass.,: Wright-Allen Press; 1971.

83. Forrester JW. System Dynamics, Systems Thinking, And Soft Or. *System Dynamics Review.* Sum-Fal 1994;10(2-3):245-256.

84. Forrester JW. Learning through system dynamics as preparation for the 21st century. Paper presented at: Systems Thinking and Dynamic Modeling Conference for K-12 Education, 1994; Concord, MA.

85. Forrester JW. Roadmaps: A guide to learning system dynamics. http://web.mit.edu/sdg/www/roadmaps.html. Accessed March 18, 2003, 2003.

86. Sterman J. *Business Dynamics: Systems Thinking and Modeling for a Complex World* NEED TO FIND CITY: McGraw-Hill/Irwin; 2000.

87. Sterman J. System dynamics modeling: tools for learning in a complex world. *California Management Review.* 2001;43(4):8-25.

88. Sterman JD. *Business dynamics: Systems thinking and modeling for a complex world.* Boston: Irwin McGraw-Hill; 2000.

89. Sterman JD. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. New York: McGraw-Hill/Irwin; 2000.

90. Sterman JD. All models are wrong: reflections on becoming a systems scientist. *System Dynamics Review.* Win 2002;18(4):501-531.

91. Sterman JD. Learning from Evidence in a Complex World. *American Journal of Public Health.* Mar 2006;96(3):1-10* not finalized.

92. McKelvey B. Complexity Theory in Organization Science: Seizing the Promise or Becoming a Fad? *Emergence.* 1999;1(1):5-32.

93. Holland J. *Hidden Order: How Adaptation Builds Complexity*. Reading, MA: Perseus Books; 1995.

94. anon. Chronicle of Higher Education Chronicle Careers: President and CEO, The Casey Family Program: Chronicle of Higher Education Chronicle Careers; 2005.

95. Cabrera D. Personal interview with William Trochim; March 2006.

96. Hammond D. Exploring the genealogy of systems thinking. *Systems Research And Behavioral Science.* Sep-Oct 2002;19(5):429-439.

97. Hammond D. *The science of synthesis : exploring the social implications of general systems theory*. Boulder: University Press of Colorado; 2003.

98. Checkland P. *Systems thinking, systems practice*. Chichester [Sussex] ; New York: J. Wiley; 1981.

99. Checkland P. From Optimizing to Learning: A Development of Systems Thinking for the 1990s. *Journal of the Operational Research Society.* Sep. 1985;36(9, Systems Thinking in Action. Conference at Henly. April 1985):757-767.

100. Checkland P. From Optimizing To Learning - A Development Of Systems Thinking For The 1990s. *Journal Of The Operational Research Society.* 1985;36(9):757-767.

101. Checkland P. *Soft systems methodology : a 30-year retrospective*. Chichester ; New York: John Wiley; 1999.

102. Checkland P, Scholes J. *Soft systems methodology in action*. Chichester, West Sussex, England ; New York: Wiley; 1990.

103. Checkland P, Scholes J. *Soft systems methodology in action : a 30-year retrospective*. [New ed. Chichester, Eng. ; New York: Wiley; 1999.

104. Checkland PB. Information-Systems And Systems Thinking - Time To Unite. *International Journal Of Information Management.* Dec 1988;8(4):239-248.

105. Checkland PB, Haynes MG. Varieties Of Systems Thinking - The Case Of Soft Systems Methodology. *System Dynamics Review.* Sum-Fal 1994;10(2-3):189-197.

106. Richmond B. System Dynamics/Systems Thinking: Let's Just Get On With It. Paper presented at: International Systems Dynamics Conference, 1994; Sterling, Scotland.

107. Richmond B. *The "thinking" in systems thinking*. 1st ed. Waltham, MA: Pegasus Communications; 2000.

108. Durant W. *The Greatest Minds and Ideas of All Time*. New York: Simon and Shuster; 2002.

109. Leischow SJ, Milstein B. Systems Thinking and Modeling for Public Health Practice. *American Journal of Public Health.* 2006;94(6):403-405* not finalized.

110. Chong L, Ray LB. Whole-istic biology. *Science.* 2002;295(5560):1661.

111. Jackson MC. *Systems thinking : creative holism for managers*. Chichester, West Sussex ; Hoboken, N.J.: John Wiley & Sons; 2003.

112. Capra F. Criteria Of Systems Thinking. *Futures.* 1985;17(5):475-478.

113. *The new vision of reality* [sound recording /]. Old Hickory, TN: Planet Tapes; 1984.

114. Capra F, Mill Valley School District (Mill Valley Calif.), Elmwood Institute. *From the parts to the whole : systems thinking in ecology and education*. S.l.: s.n. ;; 1994.

115. *New paradigm thinking* [sound recording /]. San Francisco, CA: New Dimensions Foundation; 1993.

116. *The coming revolution* [sound recording /]. San Francisco: New Dimensions; 1983.

117. Laszlo E. *The world system: models, norms, applications*. New York,: G. Braziller; 1973.

118. Laszlo E. *The inner limits of mankind : heretical reflections on today's values, culture, and politics*. Oxford [Eng.] ; New York: Pergamon Press; 1978.

119. Laszlo E. *Systems science and world order : selected studies*. 1st ed. Oxford [Oxfordshire] ; New York: Pergamon Press; 1983.

120. Laszlo E. The practical relevance of the systems sciences. http://www.club-of-budapest.org/publications/web/systems_theory.pdf. Accessed April 7, 2002, 2002.

121. Laszlo E, Club of Budapest. *Macroshift: navigating the transformation to a sustainable world*. San Francisco: Berrett-Koehler Publishers; 2001.

122. Carsten J. Seeing the forest for the trees: A manager's guide to applying systems thinking. *Personnel Psychology.* Fal 2003;56(3):765-767.

123. Cummings TG. *Systems theory for organization development*. Chichester ; New York: J. Wiley; 1980.

124. Davidz HL, Nightingale DJ, Rhodes DH. Enablers, Barriers, and Precursors to Systems Thinking Development: The Urgent Need for More Information. Paper presented at: International Conference on Systems Engineering/INCOSE; September, 2004, 2004; Las Vegas, Nevada.

125. Clemens M. http://necsi.org/projects/mclemens/syshier.gif.

126. Oxford English Dictionary: Oxford Unviersity Press; 2005.

127. ISee Systems: Borneo Problem; 2002.

128. Lovins LH, Lovins AB. *How not to parachute more cats.* Snowmass, Colorado: Rocky Mountain Institute.

129. *The Feynman Lectures on Physics [UNABRIDGED] (Audio CD)*: Basic Books; 2006.

130. Wolfram S. *A New Kind Of Science*. 1 ed: Wolfram Media; 2002.

131. Collins JC, Porras JI. *Built to last : successful habits of visionary companies*. 1st ed. New York: HarperBusiness; 1994.

132. Cabrera D. *Remedial genius : think and learn like a genius with the five principles of knowledge*. 1st ed. Loveland, Colo.: Project N Press; 2001.

133. Cabrera DA. Patterns of knowledge: knowledge as a complex, evolutionary system, an educational imperative. In: Miller R, ed. *Creating Learning Communities*. online edition ed. Brandon, VT: Solomon Press; 2002.

134. Nietzsche FW. *The birth of tragedy*. New York: Dover Publications; 1995.

135. Aristotle, McMahon JH. *The metaphysics*. Buffalo, N.Y.: Prometheus Books; 1991.

136. *Greater than the sum: systems thinking in tobacco control. Smoking and Tobacco Control Series*. Bethesda, MD: U.S. Department of Health and Human Services, National Institutes of Health, National Cancer Institute; in preparation.

137. Bertalanffy Lv. *General system theory; foundations, development, applications*. New York,: G. Braziller; 1969.

138. Cabrera D. Patterns of knowledge: knowledge as a complex, evolutionary system, an educational imperative. In: Miller R, ed. *Creating Learning Communities*. online edition ed. Brandon, VT: Solomon Press; 2002.

139. Richmond B. Systems Thinking System Dynamics - Lets Just Get On With It. *System Dynamics Review.* Sum-Fal 1994;10(2-3):135-157.

140. The Center for Quantum-Integral Medicine. http://www.quantumintegralcenter.com/about_quantum_integral_medecine.htm, 2006.

141. Green LW. Public Health Asks of Systems Science: To Advance Our Evidence-Based Practice, Can You Help Us Get More Practice-Based Evidence? *American Journal of Public Health.* 2006;96(3):1-4* not finalized.

142. Cabrera DA. Bacterial Burritos, Mixed Metaphors and a Man in the Middle: A Scientific Life at the Crossroads of Biology, Chemistry and Engineering website: . *Life Science Profiles* [http://www.genomics.cornell.edu/news/news_story.cfm?id=.

143. Lewin R, Regine B. *The soul at work : listen, respond, let go : embracing complexity science for business success*. New York: Simon & Schuster; 2000.

144. Descartes R. *Discourse on method, and Meditations*. New York,: Liberal Arts Press; 1960.

145. *The turning point* [sound recording]. Boulder, Colo.: Sounds True Recording; 1990.

146. website. http://www.kli.ac.at/institute-a.html). .

147. Scientist: A. http://www.americanscientist.org/template/BookReviewTypeDetail/assetid/28569;jsessionid=baaeYvFFhtD4Z8.

148. Tsu L. *Tao te ching*. 1st ed. New York: Knopf; 1972.

149. Szulc T. Abraham: journey of faith. *National Geographic.* Vol December 2001; 2001.

150. nobelprize.org: The Nobel Foundation; 2005.

151. Raup DM. *Extinction : bad genes or bad luck?*: Oxford University Press; 1993.

152. Margulis L, Sagan D. *Microcosmos: Four billion years of microbial evolution*. Berkeley: University of California Press; 1986.

153. Devlin K. *The language of mathematics: Making the invisible visible*. New York: W.H. Freeman and Company.; 1998.

154. Burke J. *Connections*. Boston: Little, Brown and Company; 1978.

155. Burke JP, Pestotnik SL. Antibiotic resistance-systems thinking, chaos and complexity theory. *Current Opinion in Infectious Diseases.* Augus7 1999 1999;12(4):317-319.

156. Editors. Ways of understanding. *British Medical Journal.* September 29, 2001 2001;323(7315).

157. Goldberger AL. Non-linear dynamics for clinicians: Chaos theory, fractals, and complexity at the bedside. *Lancet.* May 11 1996;347(9011):1312-1314.

158. Huz S, Andersen DF, Richardson GP, Boothroyd R. A framework for evaluating systems thinking interventions: An experimental approach to mental health system change. *System Dynamics Review.* Sum 1997;13(2):149-169.

159. Chan C-PCA. Implications of organizational learning for nursing managers from the cultural, interpersonal and systems thinking perspectives. *Nursing Inquiry.* 2001;8(3):196-199.

160. Lenaway D, Halverson P, Sotnikov S, Tilson H, Corso L, Millington W. Public Health Systems Research: Setting a National Agenda. *American Journal of Public Health.* January 31, 2006 2006;96(3):NOT FINALIZED.

161. Committee on Assuring the Health of the Public in the 21st Century, Board on Health Promotion and Disease Prevention, Academies IoMotN. *The Future of the Public's Health in the 21st Century*. Washington, DC: The National Academies Press; 2002.

162. World Health Organization. *World Health Report 2000: Health Systems: Improving Performance.* Geneva, Switzerland: World Health Organization; 2000. 924156198X.

163. Institute of Medicine. *Crossing the Quality Chasm: A New Health System for the 21st Century*. Washington, DC: National Academy Press; 2001.

164. Gerberding JL. Protecting Health--The New Research Imperative. *Journal of the American Medical Association.* September 21, 2005 2005;294(11):1403-1406.

165. http://www.ajph.org/misc/about.shtml. http://www.ajph.org/misc/about.shtml.

166. Best A. Systemic transformational change in tobacco control: An overview of the Initiative for the Study and Implementation of Systems (ISIS). *see May 2006 publication: Best, A. L., R. V. Tenkasi, W. K. Trochim, F. Y. Lau, B. H. Holmes, T. R. Huerta, G. Moor, S. Leischow, and P. I. Clark. Forthcoming. Systemic transformational change in tobacco control: An overview of the Initiative for the Study and Implementation of Systems (ISIS). In Innovation in health care: A reality check, ed. A. Casebeer, A. Harrison, and A. E. Mark. New York: Palgrave Macmillan).* . 2006.

167. W.K. Kellogg Foundation. *Partnerships: A powerful tool for improving the well-being of families and neighborhoods, Final Review Version.* Battle Creek, MI: W.K. Kellogg Foundation; 1998.

168. Agency for Healthcare Research and Quality. *Community-Based Participatory Research: Assessing the Evidence.* Rockville, MD Agency for Healthcare Research and Quality,; August 2004 2004. AHRQ Pub. No. 04-E022-1

169. University of Washington. Community-Campus Partnerships for Health: About Us; 2005.

170. Institute for Healthcare Improvement. About Us. Website]
http://www.wikinator.com/middleway/files/InstituteforHealthcareImprovement.pdf
http://www.ihi.org/ihi Accessed October 3, 2005.

171. International Healthy Cities Foundation. Overview and History; 1997-2002.

172. Partnership for the Public's Health. About the partnership: Overview; 2005.

173. Turning Point National Program Office. *From Silos to Systems: Performance Management to Improve the Public's Health.* Seattle, WA: Turning Point Performance Management Collaborative, Public Health Foundation 2003.

174. World Health Organization. Commission on Social Determinants of Health; 2005.

175. Lammers JC, Pandita V. Applying systems thinking to public health leadership. *Journal of Public Health Management & Practice.* July 1997;3(4):39-49.

176. Trochim W, Cabrera, D. The complexity of concept mapping for policy analysis *Journal of Emergence, Complexity and Organization.* 2005;7(1):11-22.

177. *Software* [computer program]. Version; 20006.

178. Weller SC, Romney AK. *Systematic data collection*. Newbury Park, CA: Sage Publications; 1988.

179. Kruskal JB, Wish M. *Multidimensional Scaling*. Beverly Hills, CA: Sage Publications; 1978.

180. Everitt B. Cluster Analysis (Second Edition) "A Review of Clustering Technique". *New York, NY: Halsted Press, Division of John Wiley & Sons, Inc.* 1980.

181. Davison ML. *Multidimensional Scaling.* New York, NY: John Wiley & Sons, Inc.; 1983.

182. Concept System Exercise: Selecting the Number of Clusters. Ithaca, NY: Concept Systems, Inc; 2005.

183. Trochim W. Reliability of Concept Mapping. *Annual Conference of the American Evaluation Association*. Dallas, Texas; 1993.

184. Trochim WMK, Cabrera D. Personal Communication. Ithaca, NY; 2005.

185. Gustafson DH, Helstad CP, Hung CF, Batalden P. The total costs of illness - a metric For health-care reform. *Hospital & Health Services Administration.* Spr 1995;40(1):154-171.

186. EVAL-SYS Listserv discussion. http://evaluation.wmich.edu/scripts/wa.exe?A1=ind0601&L=eval-sys. Accessed February 15, 2006.

187. Midgley G. Systemic Intervention for Public Health *American Journal of Public Health.* 2006;96(3):33-39* not finalized

188. Midgley G. *Systems Thinking*. London ; Thousand Oaks, Calif.: SAGE; 2003.

189. Midgley G. *Systemic Intervention: Philosophy, Methodology, and Practice*. New York: Kluwer Academic/Plenum; 2000.

190. Midgley G, Munlo I, Brown M. The Theory and Practice of Boundary Critique: Developing Housing Services for Older People *The Journal of the Operational Research Society.* May 1998 1998;49(5):467-478.

191. Donovan SM, Bransford JD, Pellegrino JW, eds. *How People Learn: Bridging Research and Practice*. Washington, D.C.: National Academy Press; 2001.

192. Evercat. Mandelpart2: Wikipedia; 2006.

193. Wikipedia. Fractal: Wikipedia; 2006.

194. Cabrera D. Personal communication with Jordan Atlas; April 2006.

195. Browning S, Shuler M. Towards the development of a minimal cell model by generalization of a model of Escherichia coli: use of dimensionless rate parameters. *Biotechnol Bioeng.* Nov 2001;76(3):187-192.

196. Haddon M. *The Curious Incident of the Dog in the Night-Time*. 1st ed. New York: Doubleday; 2003.

197. EcoSphere Care. http://www.eco-sphere.com/care_manual.htm. Accessed 2006, February 10.