Translational Systems Sciences 10

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A Guide to Systems Research

Philosophy, Processes and Practice

Springer

Translational Systems Sciences

Volume 10

In 1956, Kenneth Boulding explained the concept of General Systems Theory as a skeleton of science. He described hopes to develop a “spectrum of theories–a system of systems” which may perform the function of a “gestalt” in theoretical construction. Such “gestalts” in special fields have been of great value in directing research towards the gaps which they reveal”.

There were, at that time, other important conceptual frameworks and theories, such as cybernetics. Additional theories and applications developed later, including synergetics, cognitive science, complex adaptive systems, and many others. Some focused on principles within specific domains of knowledge and others crossed areas of knowledge and practice, along the spectrum described by Boulding.

Also in 1956, the Society for General Systems Research (now the International Society for the Systems Sciences) was founded. One of the concerns of the founders, even then, was the state of the human condition, and what science could do about it.

The present Translational Systems Sciences book series aims at cultivating a new frontier of systems sciences for contributing to the need for practical applications that benefit people.

The concept of translational research originally comes from medical science for enhancing human health and well-being. Translational medical research is often labeled as “Bench to Bedside.” It places emphasis on translating the findings in basic research (at bench) more quickly and efficiently into medical practice (at bedside). At the same time, needs and demands from practice drive the development of new and innovative ideas and concepts. In this tightly coupled process it is essential to remove barriers to multi-disciplinary collaboration.

The present series attempts to bridge and integrate basic research founded in systems concepts, logic, theories and models with systems practices and methodologies, into a process of systems research. Since both bench and bedside involve diverse stakeholder groups, including researchers, practitioners and users, translational systems science works to create common platforms for language to activate the “bench to bedside” cycle.

In order to create a resilient and sustainable society in the twenty-first century, we unquestionably need open social innovation through which we create new social values, and realize them in society by connecting diverse ideas and developing new solutions. We assume three types of social values, namely: (1) values relevant to social infrastructure such as safety, security, and amenity; (2) values created by innovation in business, economics, and management practices; and, (3) values necessary for community sustainability brought about by conflict resolution and consensus building.

The series will first approach these social values from a systems science perspective by drawing on a range of disciplines in trans-disciplinary and cross-cultural ways. They may include social systems theory, sociology, business administration, management information science, organization science, computational mathematical organization theory, economics, evolutionary economics, international political science, jurisprudence, policy science, socio-information studies, cognitive science, artificial intelligence, complex adaptive systems theory, philosophy of science, and other related disciplines. In addition, this series will promote translational systems science as a means of scientific research that facilitates the translation of findings from basic science to practical applications, and vice versa.

We believe that this book series should advance a new frontier in systems sciences by presenting theoretical and conceptual frameworks, as well as theories for design and application, for twenty-first-century socioeconomic systems in a translational and transdisciplinary context.

More information about this series at http://www.springer.com/series/11213

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ISSN 2197-8832 ISSN 2197-8840 (electronic)
Translational Systems Sciences
ISBN 978-981-10-0262-5 ISBN 978-981-10-0263-2 (eBook)
DOI 10.1007/978-981-10-0263-2

Library of Congress Control Number: 2016949454

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer Science+Business Media Singapore Pte Ltd.

Foreword

We live in a world and at a particular historical moment when the need for thinking and acting systemically, or holistically, is readily apparent. Unfortunately, as the need grows, the capacity to think and act systemically appears in decline. Thus, a book that sets out to enhance systems understandings is to be welcomed. This is particularly true in relation to research practice which is the primary concern of this book under the rubric of *systems research*. In a world where human-induced climate change exacerbates complexity, uncertainty, and surprise, it would seem to be strategically unwise not to invest in building systems research capability. Obviously, one has to appreciate the *product* to garner investment. This book has contributions from distinguished researchers with particular experiences and, importantly, different perspectives as to what systems research could be taken to be, as well as what it can become. The reader wishing to make up his and her own mind as to what investments in system research demand attention will be well-rewarded.

A book that addresses philosophy, processes, and practice presents opportunities for the experienced as well as the early career researcher; a question pertinent to both is: "How could my research be enhanced if informed by elements of philosophy, processes, and practice that these authors claim to generate 'systems research?'" To address this question, researchers have to escape the constraints of the everyday use of the word *system*. As contributors to this volume outline, there is a rich and varied history of scholarship that underpins any serious engagement with the concept system and thus with systems research. A reader of this book is well advised to appreciate that *system* is a noun, which presents certain possibilities and constraints. There are two main adjectives that derive from the word system, systemic and systematic, and these have quite different meanings, specifically, one is concerned with relational dynamics that are mainly circular and recursive (systemic), and the other is concerned with linear, step-by-step procedures (systematic). Thus the word system "holds within it" these two possibilities the systemic/systematic and these in turn can be descriptors of different, yet ideally related, forms of practice—systemic practice and/or systematic practice.

The reader will soon become aware that some authors choose to see systems as entities in the world, worthy of description, modelling, change, and so on, while others choose to see systems as a conceptual devices which, in the hands of a systemic thinker or practitioner, can be used to change the way situations are understood or transformed. These are very different research/researcher choices but with awareness and responsibility can be used to good effect to address some of the most pressing issues of our times.

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Introduction

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Welcome to *A Guide to Systems Research—Philosophy, Processes and Practice.* It is the purpose of an Introduction to launch a reader into a book. But before we direct you forward, we would like to reflect on how this book came to be.

In the introduction to one of his books, organizational theorist and systems scholar Ian Mitroff once wrote, "On the one hand, this book was generated out of the excitement, joy, and love of discovering a new way of thinking. On the other, it was also written out of the most intense mood of dissatisfaction" (Mitroff, 1983, p. xix). It could be said that a similar mood of combined enthusiasm and consternation provoked the genesis of this book on systems research.

In the fall of 2013, the International Federation for Systems Research (IFSR) requested proposals for the 2014 IFSR Conversation, a biennial meeting of philosophers, theorists, scholars, and practitioners focused on development of specific streams of thought in the systems sciences. A proposal was submitted for the formation of the Systems Research Team (SRT) to explore the question, "What distinguishes systems research from other types of research and how will we know?" After the IFSR accepted the proposal, the SRT was formed by the team leader, meeting several months by teleconference in preparation for the Conversation. In April 2014, the eight authors of this book gathered in Linz, Austria, intently exploring the topic of systems research. The members of the SRT who developed this book are seasoned systems researchers, experienced in working to extend and apply systems theoretical concepts in research ranging from the history of the social sciences to organizational behavior, from project management to sociology, and from thought ecologies to the natural sciences. Additionally, all of us came to the Conversation with startlingly fundamental questions about our work, "What makes research *systems* research?" Further, we explored an ensuing cascade of questions, such as: What are the criteria for high-caliber systems research? What is the value of systemic research in comparison and as complement to other research approaches? When using systems research, how do we explain our ontological and epistemological philosophical underpinnings? In conducting systems research, how are both the researcher and the researched system changed? We were familiar with the joke that, "If it walks like a duck and talks like a duck, then it must be a duck!" But we agreed that systems research warranted a clearer definition than that.

Throughout the week of the Conversation, we revisited our early training in academic research, wondering how rigorous research, broadly speaking, had been defined for us and taught to us in our various home disciplines. It was not difficult to recall exemplary research methods books from each of our own fields of study; there, we could point to books that transcended specific methodological schools of thought and guided our early research work. But when we turned our attention to the systems literature, it was more challenging to think of comparable research guides. Certainly, we knew our field's foremost texts on many of the *specific* schools of thought that comprise the contemporary systems community: there are respected research guides on methodologies specific to systems dynamics, critical systems thinking, soft systems methodology, complexity research, systems engineering, systems design, and many others. But what of the foundational books on how systems research ought to be conducted *regardless of one's favored methodological approach*? Where were the research method texts that encompassed and transcended all of those specific schools of systems thought? We began to wonder what such a text would say that could be useful to researchers of all methodological schools of systems thought, of any home discipline (whether of the "natural" or "social" sciences). Each day, as the SRT gathered around the table, we began to imagine others sitting with us—doctoral students and early career researchers, people deeply committed to systems and "systems skeptics." We wondered about their questions about systems research and where the answers to them could be found.

This book is a product of that week of vigorous dialogue and the collegial commitment to advancing the systems sciences among us that deepened as a result of it. *A Guide to Systems Research—Philosophy, Processes and Practice* does not replace any of the excellent texts on specific systems methods that presently exist. For readers' consideration, this guide provides possible perspectives and a framework for approaching research holistically. It can be used in addition to other systemic approaches, as well as augmenting traditional approaches to research that typically reduce a whole to parts and then attempt to reassemble the whole.

As we designed the chapters in this book, we carefully considered what topics we felt a foundational systems research text must address. As we wrote, we challenged ourselves as authors to explain why each topic was crucial to all systems research. We sought to write in a way that would assist readers in thinking through each chapter's topic as they crafted their own research inquiries. We kept in mind the kinds of missteps systems researchers can make (as we had made several of them ourselves) and how to develop research projects that can prevent or minimize such pitfalls. We understand that sound research involves difficult choices and tradeoffs and we sought to write our chapters in such a way that readers recognize this. Most importantly, we wanted readers to understand what considerations in each chapter make for *good* research—as well as good *systems* research. And so, we present this path as a way you, the reader, may approach your research using a systemic perspective.

Deborah Hammond, Ph.D., sets the pace in Chapter 1 with systems philosophy. Debora currently coordinates an MA program in Organizational Development that draws on systems thinking to facilitate change in organizations through collaborative decision-making. Her graduate work is in the history of science, focusing on the evolution of systems theory and exploring the roots of systems thinking in engineering, management, information theory, biology, ecology, and social theory. She has developed a reputation for her knowledge of the work of the founders of the Society for General Systems Research (a precursor to today's International Society for the Systems Sciences). Much of her research has focused on the implications of systems thinking for sustainability and social change. Her future work will focus on the philosophical and ethical dimensions of systems thinking, drawing on work in the field of virtue ethics. In Chapter 1, Deborah outlines the evolution of systems theory and practice, distinguishing research into the nature of systems and a systemic approach, and describing the relationship between them. She outlines ontological, epistemological, and ethical considerations involved in systems research, and the qualities of inclusivity, collaboration, and holistic thinking inherent in it. Sound systems research begins with careful consideration of the philosophical underpinnings and assumptions a researcher makes.

In Chapter 2, John Kineman, Ph.D., explores the value of using a framework to orient one's systems research. John is a senior Research Scientist and Associate Professor at the University of Colorado, Boulder, and an Adjunct Professor at Vignan University, Vadlamudi, India. John retired from the U.S. National Oceanic and Atmospheric Administration (NOAA) in 1995, having worked in ocean exploration, oil spill (crisis) research, marine ecology, global ecology, and informatics for global change research. He has also worked at the Kenya Wildlife Conservation and Management Department, Karisoke Research Centre in Rwanda, and the United Nations Environment Programme (UNEP) in Kenya. John's primary interest is complex and living system theory from inter- and transdisciplinary perspectives. His research focuses on whole systems theory and adaptive ecological niche modeling. His current educational agenda aims to establish international research collaborations focused on crisis and sustainability sciences. John holds a Bachelor's of Science degree in Physics and Earth Physics from the University of California, Los Angeles, and Masters and Ph.D. degrees in Ecosystem and Environmental Studies from the University of Colorado, Boulder. John is the 2015–2016 President of the International Society for the Systems Sciences (ISSS). In Chapter 2, John begins with the premise that a system is a whole unit of nature. From this premise, he develops a four quadrant, four category framework fundamentally relevant to other systems frameworks that have emerged independently in many disciplines. The framework he presents lends itself to mathematical rigor and to application in wide-ranging fields of scholarship and practice. Once a researcher has established a solid grounding in a theoretical or conceptual framework, the work of developing a specific research study can begin.

In Chapter 3, Mary C. Edson, Ph.D., and Louis Klein, Ph.D., discuss the intricacies of problem structuring and research design in systems research. Mary is a scholar/practitioner whose interests are advancing the application of systems research and building resilient organizations. Mary sees teams and organizations as complex adaptive social systems. She is the team leader of the SRT, whose genesis came from her doctoral work. She consults with organizational leaders to develop adaptive capacity and coaches clients as President of Equipoise Enterprises, Inc. Mary's program management and leadership experience spans more than 20 years in major corporations in the fields of healthcare, hospitality, financial services, and technology. She serves as Vice President of the Executive Committee for the International Federation for Systems Research (IFSR), and project manager for their biennial Conversations. She also teaches graduate students adaptive leadership at Union Institute and University. Her doctorate in Organizational Systems at Saybrook University focused on group development, complex adaptive systems, panarchy, and sustainability. She also holds degrees in international business from Cornell University and The Johns Hopkins University. Louis is an international expert on systemic change and complex management. He is a sought-after Ph.D. supervisor affiliated to universities in Germany, France, Denmark, and Australia. He has served as Vice President of the ISSS and serves on the board of the World Organisation for Systems and Cybernetics. In his research, he draws from his experience as an international management consultant and top executive coach to help advance the fields of systems and cybernetics. Since 2009 he has led the research group on social and cultural complexity in project management for the International Center for Project Management in Canberra, Australia. Currently, he is working on two action research-based projects, providing a systemic perspective on business excellence and the future of culture. His future ambition aims at promoting a praxeology of public entrepreneurship, business excellence, and systems research. In Chapter 3, Mary and Louis focus on how a research inquiry can be structured in a way that is both systemically and systematically rigorous. The problem structuring emphasis of their chapter guides readers in choosing how to do the right research. Their research design emphasis addresses how to do research using a systemic lens.

In Chapter 4, John J. Kineman, Ph.D., revisits the framework presented in Chapter 2 in order to discuss the use of modeling and simulation in systems research. He discusses the wide-ranging interpretations of modeling, as distinct from simulation and analogy. The perspective on modeling presented here draws the reader's attention to tensions between realist and instrumentalist approaches, as well as the need to represent constructed phenomena. Five kinds of models available to systems researchers are presented, along with recommendations for future developments in systems modeling. Modeling can be an invaluable tool for researchers to rigorously conceptualize and analyze a whole system before beginning to execute the practicalities of a research project.

In Chapter 5, Shankar Sankaran, Ph.D., delves into what, for many, is the substance of research work, taking action. Shankar is a Professor of Organizational Project Management at the University of Technology in Sydney, Australia. Starting his career as an automation engineer, Shankar started off as a "hard systems" thinker working with control systems, but soon realized the value of "soft systems thinking" when he became a manager dealing with people and "messy" problems. He currently teaches systems thinking to project management students in a Master's Program and supervises doctoral students using systems thinking and action research. Shankar initiated and now chairs the Action Research Systems Integration Group of the ISSS. He is currently involved in an Evaluative Study of Action Research with a team of international researchers to examine process and outcomes from approximately 170 action research projects worldwide to gauge their impact. Shankar completed a Master's in Systems Engineering and a Doctorate in Business and Management during which he learned to use action research. He has a great interest in the use of novel research methods that are both transformational and translational. One of his unfulfilled dreams, which will need time and patience, is to figure out how "systems thinking" is conceptualized in Eastern philosophies. In Chapter 5, Shankar adapts well-known project management practices to the undertaking of a systems research project. He addresses the "nuts and bolts" activities systems researchers face from the start of a project to its successful conclusion, including discussions of how multimethodologies can be well-handled in systems research, and how systems interventions can be incorporated into a research project. For many, the conclusion of a research project turns our focus from the practical work done in the field to the work of analyzing and writing up the findings. Given the nonlinearity of many systemic phenomena, many researchers facing the prospect of writing about their research wonder, "Where do I begin?"

In Chapter 6, Will Varey, Ph.D., addresses the challenging topic of systems research reporting. Will walks through the complexities of writing coherently about research findings. Will is a researcher in the systems sciences with a focus on sustainable social systems. His area of specialized contribution is the systemic approach to the formation of abductive research. Will is a lecturer in systems approaches to systemic change management, sustainability planning, and the formation of social learning systems. He is a member of the ISSS and Fellow of the Australian Institute of Management. His primary teaching role is the applied praxis of apithological inquiry. This research method focuses on generative systems and the generative development of researchers in the role of system curators. Will holds a Master's degree in Business Leadership and Strategic Management, and a doctorate in the analysis of thought-ecologies. In Chapter 6, Will guides researchers in approaching the reporting of systems research in a systematic way, with attention to structure, boundary, relations, timing, and completeness. He draws attention to critical choices the writer must make, common errors, and ethical tensions inherent in writing about systems research, all with the goal of helping researchers maximize the likelihood that their work will be favorably received.

In Chapter 7, Pamela Buckle Henning, Ph.D., steps back from the work of conceptualizing and executing a research project that has been the focus of the previous chapters of this book. Her chapter examines the competencies one requires to be able to perceive systems at all, and those required for one to be able to conduct systems research. Pamela is an Associate Professor of Management at the Robert B. Willumstad School of Business at Adelphi University in New York. As a management educator in the United States, she teaches organizational behavior, leadership, teamwork, group dynamics, and systemic complexity. Pamela's scholarly and clinical work is oriented around the perspective that human psychology is a complex system embedded in densely interconnected biological, interpersonal, institutional, and environmental systems. Her interests include the processes involved in scientists' systems thinking, as well as "lay epistemics" (perceptual processes used by nonscientists). She is a Visiting Fellow at the University of Bristol's Systems Centre in the United Kingdom, and serves on the Board of Directors of the ISSS. She has worked in the not-for-profit, private, and public sectors in Canada. Pamela's future research project will be a collaboration with international researchers to investigate the cognitive and emotional processes involved in systems thinking, and the worldviews and values systems of systems thinkers. In Chapter 7, Pamela draws attention to the multitude of books that have been written about the properties and behaviors of systems, but the comparative lack of writing about the competencies or skills necessary to perceive systems. This provides the launching point to the chapter's discussion on important perceptual competencies that are necessary for one to be able to perceive systems and to conduct effective systems research.

Finally, in Chapter 8 we revisit the primary question which, as we have said, was at the heart of the question that brought our team together. What distinguishes systems research from other types of research and how will we know? Gary S. Metcalf, Ph.D., and Mary C. Edson, Ph.D., tackle this topic in their discussion about evaluating the impact of systems research. Gary is a professor in the Department of Leadership and Management at Saybrook University in the United States, and is also a visiting faculty member in the Creative Sustainability program at Aalto University in Helsinki, Finland. Gary graduated from Saybrook University under the mentorship of Béla H. Bánáthy. His background includes practicing as a family systems therapist, as a manager in Fortune 500 corporations, and as a professor and consultant since 2000. He has served on the Executive Committee of the IFSR, including in the role of President. He is also a Past President of the ISSS. Gary's research and practice interests include the application of systems principles to organizations and social systems, as well as the development of theories about systems. His hope for the development of systems work would be to bring it back into the mainstream of research and policy-making at national and international levels. Gary served as Mary's Dissertation Chair at Saybrook University. The impetus for the formation and development of the SRT at the IFSR Conversations is their mutual interest in finding competent and comprehensive approaches to systemic inquiry. In their discussion, Mary and Gary develop an evaluative perspective of systems research in relation to what is missing from current scientific assumptions about research inquiry. They examine rigor in systemic research, the need for each stage in a research project to operate as a coherent whole in its own right, while also playing a part in a comprehensive overall study design. Researchers can expect their work to be evaluated on both counts. Through the collaboration that created this guide, the recommendations made are a model in that the SRT developed a holistic framework for the book itself, which the chapters reveal as an iterative learning cycle. Systems research is a learning system. The philosophy, processes, and practices presented in this guide are part of a larger whole in systemic learning. These ideas are intended to be thoughtful and thought-provoking for readers and researchers.

The authors are indebted to many who have supported our work. As in most systems, there are vital interdependencies that enable the whole to work. First among them is the IFSR, sponsors of the biennial Conversations that brought our team together. We thank Kyoichi Kijima and Hiroshi Deguchi, Editors-in-Chief of the Translational Systems Sciences Series. Professor Kijima was a staunch supporter of our ideas from the outset and we appreciate his work in introducing our book proposal to Springer Publications. At Springer, Stephen Jones was an invaluable guide throughout the publishing process. We thank the ISSS and the IFSR for their financial support of this book. Monika Landenhamer provided outstanding editorial expertise. We appreciate Ray Ison's perspective of the book in his Foreword. We thank an enthusiastic and dedicated group of doctoral students from the ISSS who volunteered to critique early drafts of our chapters: Claudia Coral, Amber Elkins, Emily Gates, Dawn Gilbert, Marty Jacobs, and Louisa Perez-Mujica. Our appreciation goes to our families, friends, and colleagues who supported us through the stresses of writing this book under ambitious deadlines including Teri Daniel, Michelle d'Arcy, Philippa Devine, Joshua Floyd, Maurice Krasnow, William Murphy, and Chen Zou, who also provided invaluable assistance, keen insights, and research support. Finally, we would like to express our gratitude to prominent scholars from around the world who have endorsed this book. To all, we appreciate that it "takes a system," in this case a dedicated, adaptive social network, to successfully bring a work like this to fruition.

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Chapter 1
Philosophical Foundations of Systems Research

Debora Hammond

Abstract This chapter serves as introduction to the evolution of systems theory and practice in order to articulate a framework for systems research. It begins with a discussion of the meaning and significance of systems research, articulating both a distinction and a relationship between *research into the nature of systems* and *a systemic approach to research*. The chapter then outlines a cyclical framework based on *relational theory*, as initially conceived by Robert Rosen and further elaborated by John Kineman, which will provide a meta-theoretical orientation and organizational framework for the remainder of the book. In order to establish a historical and theoretical context for the book, the chapter explores the evolution of the systems concept, and briefly summarizes developments in the broad ranging systems field, beginning with an overview of applied systems approaches, including both systems technology and systems design, and continuing with an exploration into the various theoretical orientations in the systems sciences. Building on this background, the chapter outlines the ontological, epistemological, and ethical considerations that inform research into systems, as well as a systemic approach to research, suggesting a potential, and perhaps critical, role for the proposed conceptual framework in facilitating a greater integration between these two approaches. Finally, it highlights the qualities of inclusivity, collaboration, and holistic thinking inherent in systems research.

Keywords Systems theory • Systems practice • Theoretical context • Ontology • Epistemology • Ethics • Inclusivity • Collaboration

> Thinking systemically is inherently collaborative.
>
> (Williams & Hummelbrunner, 2010, p. vii)

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M.C. Edson et al. (eds.), *A Guide to Systems Research*, Translational Systems Sciences 10, DOI 10.1007/978-981-10-0263-2_1

Systems Research: What and Why

The concept of systems research could be seen to have at least two distinct though related meanings: doing research from a systems perspective or doing research into the nature of systems. In offering a text on systems research, the authors seek, first, to offer a framework and approach that will be relevant from either standpoint, and perhaps also facilitate greater integration between the two. Second, we have organized this book to provide a comprehensive overview of theory, practice, and methodology relevant to such an approach.

Defining Research

At the most basic, all research might be seen as gathering information to inform action. Ultimately, it is part of a circular process of ongoing learning, based on previously obtained knowledge and experience. The scientific method involves, first, the recognition of a particular area of interest—a problem, situation, event, physical phenomenon, and so forth—that requires explanation or better understanding. The next steps represent the elaboration of a plan for gathering information about the chosen focus, generating an hypothesis to inform rationale and process for putting the plan into action, and gathering data, which then must be analyzed to elicit at least a tentative explanation of the phenomenon under investigation. This result will then inform future research, as well as any actions taken on the basis of what was learned.

This cycle of observation, reflection, planning, and acting (see Fig. 1.1) is at the heart of the framework that will be presented in this book as an organizing

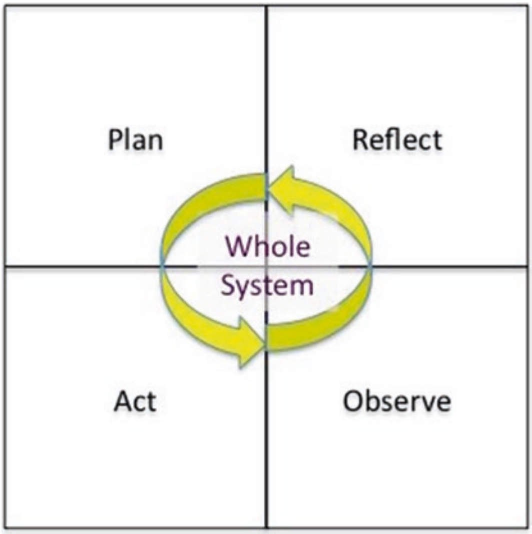

Fig. 1.1 Basic systems research framework

metatheory for understanding the nature of systems, as well as the significance and potential of a systemic approach to research (essentially ontological and epistemological considerations respectively).

The Emergence of Systems Thinking

The multifaceted systems field emerged in the mid-twentieth century out of a growing recognition of the limitations of traditional approaches to scientific research, specifically in terms of the *mechanistic* and *reductionist* assumptions at the foundation of modern science since Descartes and Newton. Part of the legacy of this orientation has been the creation of a divide between "natural" science and "social" science. This divide, between what C. P. Snow (1959) identified as the "two cultures," takes on many forms depending on the context, and might be seen as part of the problem focus for this book as a collaborative systems research project.

The broad ranging scope of developments in the systems field reflects a variety of impulses and commitments. Among the most significant for our purposes in this collaborative project is the recognition of the fragmented nature of discipline-based research and the need for a more integrated approach. The reductionist orientation of traditional science has been enormously successful in elaborating mechanisms of natural phenomena, expanding humanity's collective understanding of the universe within which we find ourselves, as well as our ability to manipulate our environment in ways that most would agree have benefitted the human species enormously (at least some of them), although this success has often come at some cost to the "whole system" (environment, other species, and perhaps the long-term viability of human habitation on the planet).

Traditional approaches to research require a narrowing of focus, in the spirit of Descartes, isolating a small part of the problem/situation/phenomenon (i.e., the system, using the term inclusively to encompass any kind of entity that can be studied), in order to understand its behavior under varying conditions. This calls to mind the often-quoted maxim, "all other things being equal." Classical science has had a tendency to marginalize and trivialize those "other things." And perhaps most critical among those other things is the role of *subjectivity* and *agency* that play such an important role in the social science side of the divide.

In seeking to understand the nature of systems, traditional science maintained an attitude of detachment and *objectivity*, until Heisenberg (1930) demonstrated that the observer cannot be separated from the observed. We as researchers (observers of nature) are embedded in the phenomena we seek to understand. We bring our biases, assumptions, and motivations, as well as the constraints imposed by the environment within which we conduct our research.

One's perception of the nature of reality determines the selection of data—what will be included and what will be excluded, the methodology for gathering the data, and the interpretation and meaning that will be drawn from the data. The motivation of the researcher (the purpose of the research) also informs the selection of data and the kinds of learning and/or action that will result.

In natural science, both theoretical and applied, the perception of reality as mechanistic is generally an unquestioned assumption. There is no room in this worldview for agency, purpose, or intelligence (other than human of course, although the question of how that evolved and functions in a mechanistic universe is never sufficiently explained). However, seen from a cyclical rather than a static perspective, information sharing, communication and learning are an integral part of the evolutionary process, which can be observed even at the atomic and molecular level.

Implications for Research

Returning to the initial distinction between two different ways of defining systems research, the motivation for research in the natural sciences is generally oriented around research into the nature of systems. The purpose of such research is to build on the body of knowledge in a particular discipline and, eventually, to apply that knowledge to a particular end. The distinction between theoretical or "pure" science and applied science results from the institutional structure within which these pursuits are—to a large extent—isolated from one another, not to mention the social and environmental contexts within which scientific research is both conducted and applied.

In the social sciences, and the biological sciences as well, research is still concerned with the nature of systems, although the greater role of the environment in social and biological systems requires a somewhat different approach. One might see natural law as a constraining environment for physical systems, but this context remains essentially unchanging. In seeking to understand the behavior of living and other complex systems, the environment emerges as a critical factor, the processes of *feedback* and learning play a much more pivotal role, and the reductionist paradigm becomes increasingly inadequate. Indeed, it is in connection with his research in the biological sciences that Ludwig von Bertalanffy initially proposed the concept of *general systems theory* in the early twentieth century.[1] The *emergence* of the ecosystem concept (Tansley, 1935) and the subsequent growth of ecology as a scientific field of study during this same time period reflect the growing awareness of the importance of considering the "environment" as popularly understood.

Further complications in studying the nature of human systems are the roles that subjectivity and objectivity play in the behavior of human actors in the system. These distinctions are probably the most critical factors in creating the divide between natural and social science. The commitment to objectivity in the former precludes

[1] von Bertalanffy initially introduced the concept of general systems theory in a lecture at the University of Chicago in 1937; it was presented to a larger audience at the Alpbach Symposium in 1948 (Hammond, 2003, p. 118; also von Bertalanffy, 1968).

consideration of consciousness, interpretation, meaning, motivation, purpose, and so forth, within the systems being studied. Of course, these dimensions are recognized as embodied within the researchers themselves and are clearly present within the process of conducting the research, yet they are not considered as relevant to the research into the system itself.

It is within the context of the social and biological sciences that doing research from a systemic perspective or orientation becomes more compelling, although this approach is ultimately relevant in the physical sciences as well. This systemic orientation requires a broadening of focus to include whole systems, with the recognition that any research also requires a clearly defined and bounded system. Thus the researcher must seek to be as inclusive as possible in relation to the focus of the research, while acknowledging and providing a clear rationale for the delineation of a particular boundary, and being aware of potential influences from outside the *boundaries* of the system thus identified. These kinds of considerations inform the emergence of the concept of *holons* or the *holarchic* nature of reality, originally introduced by Arthur Koestler (1970) to describe the concept of a multilayered structure of systems within systems. This multilayered structure is also described in terms of *hierarchy*, although that term is often understood to imply hierarchies of power, which is not necessarily the case in the holarchic sense.

Systems and Circularity

A systemic approach to research requires a much more robust examination of the interrelationships among the various components of the system being studied, as well as between the system and the larger environment. As previously stated, living systems are characterized by feedback and learning—which are circular or nonlinear processes—and function according to the basic systems research framework outlined above—observe, reflect, plan, and act. Although these terms imply an anthropomorphic connotation, they can be reconceived in ways that are relevant to both physical and biological systems, without changing the essential nature of the framework. The cycle, as thus elaborated, implies some level of decision-making at all levels of the system, in response to both internal interactions and external information and constraints. This decision-making process can be unconscious and predetermined (in most physical and biological systems) or subject to conscious evaluation and choice (in most human systems).

The systems research framework that is being introduced in this volume is based on the work of Robert Rosen (1958) on relational theory, which was further developed by one of our co-authors, John J. Kineman (2011, 2012). The emphasis on relation is key. Joanna Macy (1991) provided some useful insights on the nature of this relation in her comprehensive discussion of *mutual causality*, comparing Buddhism and systems theory in articulating the concept of dependent co-arising. A systemic orientation need not appeal to external intelligence or a supernatural designer to account for purpose or intelligence within the evolutionary cycle.

Instead, a systems orientation to understanding the nature of reality highlights interrelationship, mutual causality, and the potential for the emergence of novelty, which is not necessarily predictable. This perspective places the researcher back in the system as an integral part of the system, not as an objective external observer. Essentially, it reinforces the conception of a *participatory universe*, articulated by John Wheeler (1994) in connection with his work on quantum mechanics.

The systems view of reality, along with the related notion of a participatory universe, has important philosophical implications. The purpose of this chapter is to articulate *ontological*, *epistemological*, and *ethical* considerations in conducting research—both into the nature of systems and from a systemic orientation. In order to provide some context, it will be helpful to begin with some background on the emergence of systems ideas.

Conceptualizing Systems

The concept of system as an organizing framework for scientific research emerged in the mid-twentieth century, growing out of a number of parallel and related developments in theoretical and applied science. The Newtonian framework, which had guided scientific inquiry for three centuries, was initially challenged by developments in physics, the iconic discipline of classical science. In exposing the limitations of the mechanistic and reductionist orientation inherent in that approach, relativity theory and quantum mechanics transformed humanity's collective understanding of matter, energy, and time as less rigidly fixed than previously conceived. More importantly, these theories called into question reigning assumptions about predictability, determinism, and scientific objectivity. The observer could no longer be seen as outside and separate from the phenomena being observed.

Developments in the biological sciences—the emerging understanding of feedback processes and the concept of living organisms as *open systems*—highlighted the need for a new conceptual framework to adequately address the *complexity* of these systems. Generally recognized as the "father" of general systems theory, Ludwig von Bertalanffy proposed the concept of organismic biology in the early twentieth century as an alternative to the mechanistic paradigm, then dominant in the life sciences. Arguing that the laws of physics and chemistry were insufficient to explain the complex organization in living systems, he believed that the laws of organization were emergent properties that could be studied scientifically. Perhaps his most important contribution to the evolution of systems ideas, the concept of open systems highlighted the capacity for *self-organization*, creativity, and spontaneity in the behavior and evolution of living systems.

Many of the insights emerging in the biological sciences in the early twentieth century were echoed in the engineering sciences, and, in fact, there was considerable cross-fertilization between these two fields (see Haraway, 1976; Weiss, 1939). In seeking to understand complex patterns of organization, interrelationship, and developmental change, biologists often drew analogies from mechanical systems. As engineering became increasingly sophisticated, the models and metaphors for understanding living systems evolved accordingly, from mechanical levers and pulleys, as in seventeenth century descriptions of circulation in the body, to conceptualizing living organisms as information processing systems in the twentieth century. Notable in this regard is the work of Paul Weiss (1939, 1973), who applied systems concepts from engineering to explain organizational processes in embryology, which shaped the development of von Bertalanffy's thought (see Haraway, 1976; Hammond, 2003).

A critical dimension in understanding organizational patterns and processes—in both living and sophisticated technological systems—is a recognition of the important role of feedback processes and circular, or nonlinear, causal relations. Articulating the processes of homeostasis in living organisms by drawing on the earlier works of French physiologist Claude Bernard (1865), Lawrence Henderson (1913) and Walter Cannon (1932) reinforced a more holistic approach to understanding both biological and social phenomena. A related development that contributed to a growing emphasis on the importance of information and communication in complex systems was Claude Shannon and Warren Weaver's (1949) elaboration of *information theory* in *The Mathematical Theory of Communication*.

Perhaps the most significant example of cross-fertilization between these emerging systems-oriented sciences is the series of 10 conferences on what came to be known as *cybernetics*, hosted by the Macy Foundation between 1946 and 1953 (see Heims, 1991). The motivation for convening the conferences was the recognition of similar patterns of self-corrective feedback processes in a broad range of disciplines, and they brought together researchers from fields as diverse as mathematics, physics, engineering, computer science, neurophysiology, psychology and psychiatry, anthropology, sociology, and philosophy.

In their seminal paper on "Behavior, Purpose and Teleology," which provided the initial impetus for the conferences, Arturo Rosenblueth, Norbert Wiener, and Julian Bigelow (1943) suggested that "all *purposive behavior* [emphasis added] may be considered to require negative feedback" (p. 19) thus providing a lens through which non-mechanistic aspects of system behavior might be incorporated. The processes of feedback came to be seen as the basis for *self-regulation* and self-organization in complex systems.

Gregory Bateson (1972), a member of the cybernetics group, described "the subject matter of cybernetics [as] not events and objects, but the information 'carried' by events and objects" (pp. 401–402). Perhaps even more presciently, Norbert Wiener, who popularized the term in his 1948 book, *Cybernetics: Or Control and Communication in the Animal and the Machine,* wrote:

> It is the thesis of this book that society can only be understood through a study of the messages and communication facilities which belong to it; and that, in the future development of these messages and communication facilities, messages between man and machines, between machines and man, and between machine and machine are destined to play an ever-increasing part. (p. 16)

Although not a member of the original group, Stafford Beer (1966), an active member of the American Society for Cybernetics,[2] echoed this theme, providing a

[2] The website for the American Society for Cybernetics (http://asc-cybernetics.org) provides a wealth of information about this fascinating chapter in intellectual history.

useful transition from the theoretical to the applied sciences in his application of cybernetics to problems in management: “Cybernetics is the science of effective organization. It studies the flow of information round a system, and the way in which this information is used by the system as a means of controlling itself” (p. 254).

In parallel with theoretical developments in the physical and life sciences, emerging technologies in the energy, transportation, and communication sectors fostered an unprecedented growth of large-scale organizational structures in both public and private sectors (Boulding, 1953). Operating at the interface between human, technological, and ecological systems, these organizations required a far more sophisticated approach to coordinating the various components of their operations.

Understanding the nature and source of organization in complex systems became increasingly critical in the wake of the technological revolutions that so profoundly transformed the nature of human existence. Applying that understanding in the design of both technological and human systems emerged as one of the key aims of developments in the systems field, with a proliferation of methodologies for applying systems insights in addressing the increasingly intractable problems confronting humanity.

In discussing the emerging field, von Bertalanffy (1968) identified three distinct orientations: *systems technology*, *systems science*, and *systems philosophy*, which he believed entailed unique perspectives, approaches and, occasionally, mutually incompatible commitments. More recently, in his Bertalanffy lecture at the 2014 Annual Meeting of the International Society for the Systems Sciences (ISSS), David Rousseau expanded the systems technology orientation to encompass *systems design*. Either formulation highlights the dialectic between theory and practice, suggesting a potential role for systems research as mediator between the various orientations, in fostering a more systemic orientation and facilitating greater integration across disciplinary boundaries. In order to explore the nature of this role, it is necessary to articulate what is meant by a systems approach and what might be the common assumptions across the range of systems approaches, both theoretical and applied. To that end, a brief overview of the history of systems thinking will provide some context to address these questions.

Evolution of the Systems Field

Both von Bertalanffy’s (1968) and Rousseau’s (2014) articulation of the various categories of systems thinking—technology/design, science, and philosophy— provide a framework for exploring the evolution of the field. It also begs the question of the distinction between various types of systems. Although these categories are somewhat fluid, it might be useful to identify the following five distinct types[3]:

[3] Along similar lines, Kenneth Boulding (1956a, 1968), together with von Bertalanffy one of the five original founders of the Society for General Systems Research (now ISSS), identified nine different types of systems as a conceptual framework for the systems sciences: frameworks, clockworks, thermostats, open systems, plants, animals, humans, symbolic systems, social systems.

- physical systems;
- technological systems;
- living systems, including both individual organisms and ecological communities;
- human/social systems: economic, political, educational, medical, and so forth;
- symbolic systems.

Although the three subfields—technology/design, science, and philosophy—emerged more or less simultaneously, they developed along relatively independent trajectories, nevertheless with a certain amount of cross-fertilization. Beginning with systems technology and design, which might also be described as "applied" systems sciences, the following section will provide a brief schematic summary of the developments in this area. Although closely related and often mutually influential, systems applications in technological systems can be distinguished from the application of systems concepts in the organization and management of social systems.

Applied Systems Approaches: Technology and Design

In looking at the applications of systems approaches in technological systems, it is helpful to distinguish between systems engineering, which deals primarily with the technological dimensions of a system, and the related fields of systems analysis, operations research, and management science, which deal more directly with the organization and management of both human and technological dimensions of evolving complex organizational structures.

Systems engineering can be defined as the design, development, production, and operation of large complex physical systems. The origin of systems engineering is generally traced to Bell Labs in the early 1940s, and—perhaps by necessity—the field tended to be somewhat more "systemic" from the very beginning than parallel developments in organizational management. Complex engineering projects required a comprehensive analysis of the system as a whole, with input from and ongoing evaluation of the system in relation to its environment, including the human systems involved in the production and eventual use of the product (Hall, 1962).

This process follows the basic format of the cyclical framework proposed above, although expanded into seven steps, as outlined by the International Council on Systems Engineering (INCOSE, n.d.): "State the problem, Investigate alternatives, Model the system, Integrate, Launch the system, Assess performance, and Re-evaluate" ("What is Systems Engineering," para. 4; see also Chapter 8, Appendix "Systems Engineering").

As technologies, and thus the organizational structures involved in their implementation, became increasingly complex, the application of systems approaches can be seen in techniques for optimizing decisions (systems analysis), coordinating logistics (operations research), and managing human participants in the systems (management science). Clearly, these three areas are closely interconnected and these definitions should be seen as broad and overlapping generalizations.

Initially, these three fields tended to draw on and operate according to fairly mechanistic principles and procedures and, along with systems engineering, are often referred to as "hard" systems approaches. This was primarily because they did not adequately account for the actual experience of the individuals involved in the system's functioning, but instead tended to portray the systemic relationships in objective and quantitative terms.

In his discussion of systemic methodology, Gerald Midgley (2000) identified three waves of systemic inquiry that reflect a shift in focus from systems technology to a more collaborative process of systems design and a corresponding transition from "hard" to "soft" systems methodologies. He described the first wave as emerging out of a confluence of developments in the first half of the twentieth century, including scientific management, human relations, operations research, and action research. It is important to note here that action research, initially introduced by Kurt Lewin, was unique in seeking input from all relevant members of the system under investigation (see Reason & Bradbury, 2008).

Emerging in the 1970s, the second wave in the evolution of applied systems, often described as *soft systems* approaches, integrated a more explicit focus on the human experiential dimension, recognizing the significance of meaning and purpose in human activity systems, and emphasizing the importance of including relevant stakeholders in the process of inquiry and decision making. Related developments included, among others:

- inquiring systems design, based on the work of West Churchman (1971);
- soft-systems methodology, developed by Peter Checkland (1981); and
- interactive management, articulated by Russell Ackoff (1974).

Drawing on insights gained from these initiatives, the third wave Midgley identified is the "critical systems" approach, which began in the 1980s, drawing on Werner Ulrich's (1983) critical systems heuristics in addressing issues of power relationships in organizations and adopting a more overtly emancipatory orientation. This approach is reflected in the works of Robert Flood and Mike Jackson (1991) and Midgley (1995). These developments in the systems technology and design field informed the theoretical orientation of systems science (see Hammond, 2014 for a more comprehensive discussion of applied systems theory).

Systems Science: Understanding the Nature of Systems

In parallel with these efforts to manage increasingly complex technological and organizational systems, three primary fields emerged in the 1950s and 1960s, with a more theoretical emphasis on articulating the dynamics of complex systems:

- cybernetics, which grew out of the Macy conferences of the 1940s and 1950s;
- general systems theory, initially proposed by von Bertalanffy and developed in the context of the Society for General Systems Research in the 1950s, and
- *system dynamics*, which built on the work of Jay Forrester in the 1960s.

Cybernetics grew out of the recognition of *nonlinear* or *circular causality*, exploring the role of positive and negative feedback in biological, technological, and social systems, particularly in terms of information flows. An understanding of feedback processes provided insights into the structural relationships of complex systems and helped to explain the operation of self-organization in human, technological, and natural systems. As the field evolved, there was more of an emphasis on what became known as *second order cybernetics*, drawing on the work of Heinz von Foerster (1974) and Gregory Bateson (1972), which highlighted the significance of the observer and the role of consciousness, cognition, perception, meaning-making, and self-reflexivity.

The field of system dynamics, based on the work of Jay Forrester (1961), was also concerned with positive and negative feedback, although less in terms of information flows and more in terms of the internal dynamics of a system, which could be modeled using causal loop diagrams. In addition, systems dynamics sought to explain the material stocks and flows in a system. In contrast to the field of cybernetics, system dynamics tended to reinforce a more objective approach to understanding and managing complex systems (see Richardson, 1991).

General system theory grew out of a much broader orientation than either of the other two fields, as it sought to identify general principles that characterized complex systems across the disciplinary spectrum. The concept of feedback, or nonlinear causality, was clearly significant in this regard, as were such concepts as emergence, the hierarchical (or holarchic) organization of complex systems, the capacity for self-organization and learning, and the role of perception, interpretation, meaning, and purpose in human systems.

Systems Philosophy: Implications for Research

It was the significance of systems philosophy about which von Bertalanffy was perhaps most passionate. He saw systems theory as providing an alternative to the mechanistic models dominating the science of his times. For him, the *mechanistic worldview* could be blamed for many of the evils plaguing the world, particularly in relation to what he called the "robot model" of humanity. In fact, he believed that systems theory offered a new way of conceptualizing reality that honored the autonomy and creativity of living systems.

In the introduction to *Systems Concepts in Action: A Practitioner's Toolkit* (2010), Bob Williams and Richard Hummelbrunner begin with a discussion of three primary orientations that they believe characterize a systems approach:

- An understanding of interrelationships
- A commitment to *multiple perspectives*
- An awareness of boundaries (p. 3).

In broad terms, these characteristics might be seen as reflecting the ontological, epistemological, and ethical implications of a systems view respectively: systems *ontology* concerning itself with the dynamics of relationships within a system and between the system and its environment; systems *epistemology* necessitating a more inclusive understanding from viewpoints both within and from outside of the system, rather than from a single "objective" observer point of view; and systems *ethics* that is building on this inclusivity, and reinforcing a much broader consideration of actors within and outside of a system.

Ontological Considerations

With regard to the ontology of systems, there are two questions to consider: one focusing on the ontology of a system (i.e., what is a system?), which corresponds with research into the nature of systems. The second question focuses on a systems ontology (i.e., what is the nature of reality from a systems orientation?), which is relevant in the process of doing research from a systemic perspective.

In addressing the first question, it is important to understand that a system is not so much a "thing" as a process. This approach resonates with *Process Philosophy*, introduced by Alfred North Whitehead (1929), who worked closely with Henderson and Cannon. All three scholars had considerable influence in the evolution of certain branches of systems theory (see Miller, 1978). The emphasis in this view is on change—the process of becoming, rather than static states of being. It portrays the nature of reality as a continual flow of matter, energy, and information.

Building on the work of John J. Kineman (2011, 2012), the authors of this volume adopted the four-quadrant shared framework, which articulates an evolutionary progression through a cycle of observation, reflection, planning, and action. The nature of this systems research framework is dynamic and highlights the ontology (being-ness) of a system as process, embedded in interactive patterns of relationship. The cyclical progression illustrates the evolutionary potential of feedback processes, as the system responds to inputs from the environment as well as changes in its own internal dynamics resulting from previous action.

Research into the nature of systems involves an articulation of the mechanisms involved in a particular system's behavior; in essence, it is a search for an underlying causal explanation. In seeking to understand a system, questions of ontology ultimately involve questions of history. The epitome of this kind of focus is research into the origin of the universe. Moving in the opposite direction around the four-quadrant framework, one can begin with the universe as the focus for the investigation, and seek to explain the dynamics that account for the observed phenomena. This leads to the discovery of certain patterns and laws that inform the dynamics of the system, which—though not necessarily conscious or purposive—constrain the available options in the evolution of the system.

The activities identified in each of the four quadrants of this framework reflect the *four causes* initially proposed by Aristotle (see Falcon, 2012):

- Observation: identification of the material system—material cause;
- Action: identification of the dynamics of the system—efficient cause;

- Planning: the constraints operating in the choice of action, whether conscious or not—formal cause;
- Reflection: building on prior evolutionary states, the condition from which the other causes flow—final cause.

Although the latter two categories have been trivialized and deemed irrelevant in modern science, understanding the four causes in a cyclical rather than a linear progression provides insights into the evolution and mechanisms of physical systems, as well as technological, living, human/social, and symbolic systems. One can discover the chemical composition and structure of a rock, for example, but it takes geological analysis (including the location of the particular sample) to explain its particular history and how it came to be what it is.

In my own work, "Philosophical and Ethical Foundations of Systems Thinking" (Hammond, 2005), I explored the second question regarding systems ontology. Beginning with an emphasis on the holistic nature of reality and the importance of considering relationships, both among the components of a system and with the larger environment, a systems-oriented ontology highlights organization, interaction, and interdependence, shifting from the atomistic and individualistic orientation of the mechanistic worldview to a more organic conception of nature and an appreciation of the patterns and processes of relationship.

In addition to the phenomenon of feedback, the concept of emergence is central in understanding the implications of a systemic worldview. In the simplest terms, the concept of emergence suggests that the whole is more than the sum of its parts, or that systems cannot be understood nor their behavior predicted based solely on information relating to the individual parts. Through the interaction of the individual components, novel qualities and phenomena emerge. In contrast to the analytical orientation of classical science, a systemic approach engenders a consideration of whole systems.

Growing out of this awareness, another key concept is an appreciation for the hierarchical or holarchic organization of complex systems. Just as systems cannot be understood by examining the individual parts, it is essential to understand systems in the context of their environment; hence, system and environment comprise an interactive process. From this perspective, there are many levels of organization within complex systems. The constituent parts of a system at one level are often complex systems themselves, embedded in the environment of the higher-level system, and containing their own interacting components.

It is the interactive process between the system and its environment and the dynamics of feedback that result from this interaction that nurtures the emergence of sophisticated properties that characterize complex systems, such as the capacity for learning and self-organization. In the context of human systems, this highlights the role of perception, interpretation, meaning, and purpose as an integral part of the system, which are critical to an understanding of epistemological and ethical implications of a systems orientation.

Epistemological Insights

An essential starting point for a systemic epistemology, and thus for research from a systemic orientation, is the recognition of the *observer* as an integral part of the system, which is a departure from the classical assumption of a neutral objective standpoint outside of the system. This is particularly important when dealing with human systems where, as Kenneth Boulding (1956b, 1968) has pointed out, knowledge of the system becomes an important part of the system. This is actually true in relation to physical, technological, and biological systems as well, which might be most easily seen in the evolution of computer technology. Further, in the process of observing natural systems, an observer brings assumptions, biases, and motivations that influence the process of observation.

From a systems perspective, knowledge is a dynamic and dialectical process of interacting with a system. The following are some questions and considerations that a systems-oriented researcher might want to consider as a starting point:

- What is my own relationship with the system I intend to study?
- What conceptual framework is guiding my choice of research topic?
- What assumptions, beliefs, and values am I bringing to the research?
- What do I hope to learn?
- What impact will my research have on the system?
- What possible blind spots might I need to consider?
- How might I gain insights from the system itself?

The last question is particularly relevant in connection with human systems, although a systemic epistemology highlights the need to consider multiple perspectives in research into any kind of system, where these questions might be expanded to address the following considerations:

- What might I learn from other disciplinary perspectives?
- What aspects of the system's environment might be relevant to my research?
- How will my research affect the larger social or ecological environment of the system?

The epistemological dimension is reflected in the two right hand quadrants of our shared framework—observe and reflect—which then imply a further iteration of planning and action. The shared framework thus transcends the traditional separation between theory and practice and supports a more collaborative approach to research. The appreciation for the pluralistic and participatory nature of systemic knowledge as an evolutionary process of perception, interpretation, and creation of meaning, has nurtured the development of systems methodologies with an explicitly ethical commitment to inclusivity.

Ethical Implications

A fundamental orientation in systemic research is a consideration of *purpose* as an integral part of the research process. Based on his understanding of human systems as purposeful systems, composed of purposeful parts, and also part of larger purposeful systems, Russell Ackoff (1974) described the challenge of management as designing human systems in ways that can "serve their own purposes, the purposes of the purposeful parts, and the purposes of the larger systems of which they are a part" (p. 18).

The questions posed in the previous section challenge the systems-oriented researcher to consider the possible implications of their research in relation to the purposes of both the purposeful parts of the system, as well as the purposes of the larger system. This latter concern is equally relevant in nonhuman systems. Engaging the question of purpose illuminates some key principles of a systemic ethic. Recognizing the embeddedness of both research and researcher in a larger social and ecological context, it is important to understand the possible ramifications of the research project in the larger system. Perhaps some additional questions to be considered are:

- Whose interests does the research serve?
- Are there aspects of the system that might be negatively impacted by my research?
- What are my own motivations in doing the research?

Considering a systems-oriented research project in the context of the larger environment recalls the concept of a participatory universe. As an integral part of the universe so conceived, one might consider systems research not as something *done to* a system, but rather conducted in *partnership with* a system. This is clearly evident in the participatory methodologies that have emerged in the context of social systems, with an emphasis on collaborative design processes. It is somewhat more challenging to consider what it might mean in relation to nonhuman systems.

In order to address this question, it is helpful to consider a classification of ethical orientations introduced by Carolyn Merchant (1992). Initially, she proposed three ethical orientations: *egocentric*, *homocentric*, and *eco-centric*. Clearly, the first orientation is focused solely on considerations of personal benefit, while the second takes into account the interests of humanity as a whole, and the third proposes concern with the larger ecological context. In her later work, Merchant (2003) expanded these categories to include a fourth category of *partnership ethics*, which she described as grounded in the "concept of relation" (p. 223).

Riane Eisler (2003) has also popularized the concept of partnership systems in contrast to dominator systems. According to the Center for Partnership Studies (n.d.), which promotes a cultural transition toward more collaborative ways of relating to one another:

> There are two fundamental ways of organizing beliefs and institutions: the partnership system and the domination system. The degree to which a society or organization orients to the domination or partnership side of the partnership-domination continuum profoundly affects how we relate to ourselves, one another, and nature. ("The Domination-Partnership Systems Continuum," para. 2)

It is within this perspective that we might consider the implications of a participatory ethic in nonhuman systems. West Churchman, former President of the ISSS, offered some compelling observations in this regard. Described by Robert Flood (1999) as the moral conscience of the systems field, Churchman believed that science should address itself to the serious problems confronting humanity, and further that scientists should be responsible for the social (and I would suggest also ecological) consequences of their discoveries (pp. 61–68).

An important example in the physical sciences that embodies this orientation is the emergence of the relatively new field of green chemistry, which is defined by the U.S. Environmental Protection Agency (n.d.) as "the design of chemical products and processes that reduce or eliminate the generation of hazardous substances" ("Green Chemistry," para. 1). Noting the systemic interrelationship of developments in this field, the agency goes on to state that the "EPA's efforts to speed the adoption of this revolutionary and diverse discipline have led to significant environmental benefits, innovation and a strengthened economy" ("Green Chemistry," para. 1).

One of the most critical ethical considerations is the question of *boundaries*; good systems research is broadly inclusive. It must be clear about the reasons for the boundaries it draws around the system under consideration, what is being left out, and possible consequences of those choices. Ultimately, good systems research supports the cultivation of whole systems thinking. Good systems research seeks to nurture the health and integrity of the systems it serves and to manage the systems that structure our lives in ways that honor the needs and purposes of all participants in the system, as well as the larger environment within which that system functions.

Concluding Reflections on Systems Research

Traditional research, in the spirit of Sir Francis Bacon, sought to understand the world in order to be better able to predict and control the external environment, assumed a posture of detachment in relation to the phenomena under observation, and presumed the existence—and aspired to the mastery—of a stable objective truth. This assumption of objectivity marginalized considerations of values and subjective experience. A systemic approach eliminates the separation between knowledge and action, and calls for a much more inclusive and comprehensive orientation, encompassing a multidimensional analysis—scientific, sociopolitical, economic, environmental, and so forth— and the inclusion of all relevant stakeholders in the determination of future actions.

Ultimately, a systemic orientation to research might be seen as nurturing a transition from control to collaboration, from competitive relationships to a greater recognition of interdependence, from hierarchical to participatory decision-making processes, and from objectivity to reflexive self-awareness.

As the world becomes increasingly complex and human systems increasingly interdependent, it is essential that humanity learns how to manage the organizations that structure our lives in ways that honor the needs and purposes of all participants in the system, as well as the larger environment within which that system functions. While traditional discipline-based research provides a foundation for whole system understanding and effective action, it lacks an adequate model for integrating the fragmented pieces into a coherent whole. Systems research provides a framework for meaningful multidimensional synthesis of the situation or problem under consideration and, as much as possible, integrates perspectives from all aspects of the system.

In the chapters that follow, this approach will be elaborated in greater depth. The next chapter will provide a comprehensive overview of the four-quadrant framework that informs this collaborative work. Chapter 3 provides guidelines for structuring research problems and developing an effective research design. Chapter 4 explores the use of models in structuring the research process, organizing data, and understanding the system being studied. Chapter 5 articulates various methodologies for carrying out the research. Chapter 6 outlines approaches to reporting research. Chapter 7 examines the competencies required for good systems research, and the final Chapter 8 provides guidelines for evaluating research.

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Chapter 2
Systems Research Framework

John J. Kineman

Abstract In this chapter, we make the proposal that a system is a whole unit of nature. We then propose a systems research framework, specifically the PAR Holon Framework that can yield a holistic form of systems analysis. By *whole* is meant a natural unit that is a self-related cycle of causes. The concept of systems has been around since the earliest philosophical records. To date, we do not have a widely accepted definition. The schema we present is based on the work of the mathematical biologist Robert Rosen and it follows, with important modifications, the causal and categorical definitions given by Aristotle. The resulting four-quadrant, four-category framework is then described and related to other meta-system frameworks that exist independently in many disciplines. There are two keys to understanding this framework. One is that since Aristotle we have thought of causality in a dualistic, hierarchical way, with ultimately unknowable causes at the top and inert substance at the bottom. Natural science has focused on the bottom half and humanistic and social sciences have focused on the top. Prior to Greek philosophy, however, in *nondual* philosophy, these same causes were described as a self-related cycle, giving a holographic view of reality. By reinventing the causal cycle in mathematical terms we remove the problem of *unnatural* causes. The entirely natural treatment of the four causes then lends itself to mathematical rigor and many applications in science, humanism, and other fields. Examples and worksheets are provided to help introduce the reader to this highly systemic way of thinking.

Keywords PAR Holon Framework • Systems analysis • Modeling relation • Holism • Causality • Category • Hierarchy • Duality • Holographic view

> All things physical are information theoretic in origin—this is a participatory universe.
> John Archibald Wheeler (Zurek, 1990, p. 5).

In this chapter, we will look at a general analytical framework for systems research and scholarship that has very deep roots and extends, in various forms, throughout science, the arts, and all of academia. Ideally, we are looking for a general way of understanding complex systems.

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M.C. Edson et al. (eds.), *A Guide to Systems Research*, Translational Systems Sciences 10, DOI 10.1007/978-981-10-0263-2_2

Considering the wide range of philosophical views about Systems (Chapter 1), and the idea of *requisite variety* (Ashby, 1956),[1] for understanding complex natural and human systems, it is natural in systems fields to employ some form of "mixed methods" research (Creswell, 2013; Halcomb & Hickman, 2015). Nevertheless, we need a way of resolving seriously unproductive divisions, such as that classically described in C. P. Snow's (1993) book, *Two Cultures*. Furthermore, a many methods approach still may not capture the essence of a complex system. In each method, especially in the sciences, our struggle for knowledge depends on translating experience into specific concepts that we find familiar and easy to grasp. This naturally sorts into specialized views, and by default, the classical view is what they all have in common. We might then wonder if the necessary variety for describing complex nature can itself be captured in a single framework or if complexity necessarily implies pluralistic views that cannot be unified. The systems sciences include many views and a wide typological scope on these issues, including a search for unity (Rousseau, Billingham, Wilby, & Blachfellner, 2016a, 2016b, 2016c).

It is important, however, to distinguish between unity and reduction. A model of unity can exist at a more general level of specificity, thus allowing for multiple kinds of special system reductions. Traditional mechanistic or materialistic reductionism, as it evolved in the modern era of science, was distillation to absolute concepts of nature, with the hope that it would prove sufficient for explaining all phenomena. Instead, it demonstrated that what seems absolute at one level may be relative at another.

A unifying analytical framework, on the other hand, might claim to be general without claiming to substitute for more specific theories. The question then is: Where do other theories fit within that general framework? Of course, whether or not the framework is truly general will necessarily remain an open question subject to testing. Still, it is the case that: "A common, classificatory framework is needed to facilitate multidisciplinary efforts toward a better understanding of complex SESs[2] [because]…entirely different frameworks, theories, and models are used by different disciplines to analyze their parts of the complex multilevel whole" (Ostrom, 2009, p. 420).

There are at least two ways to develop a general systems framework. One is to build "bridges" between diverse theories, methods, and views (Friendshuh & Troncale, 2012; Rousseau et al., 2016b; Venkatesh, Brown, & Bala, 2013). Another is to find a general pattern that is common to all systems (Falcon, 2012; Kineman, Banathy, & Rosen, 2007; Koestler, 1970). As William of Occam (1287–1347)

[1] Requisite variety refers to systemic stability and regulation. Essentially, the number of states of control mechanisms must be equal or greater than the number of states in the system being controlled. As Ashby (1956) stated, "Variety can destroy variety" (p. 124).

[2] Socio-ecological systems or social ecological systems.

famously noted, we favor those concepts that facilitate our understanding with the fewest assumptions—the principle of parsimony. Thus, the second approach is pursued for deeper understanding, economy and elegance, even though the diversity implicit in the first approach is needed to test it.

The framework discussed here was derived in the most general way possible, primarily from two sources: relational biology, which provides most of the theory in this chapter, and participatory action research (PAR), which is described in Chapter 5. The first source for the framework, relational biology, began in the 1950s at the University of Chicago with mathematical biologists Robert Rosen and Nicholas Rashevsky. Their question was, "What is life itself," meaning, what causes it, not just what it does. Rosen concluded that the answer lies in a fundamental "modeling relation" that not only characterizes knowledge in the human sciences but also represents analogous processes in nature (R. Rosen, 1985, 1991, 1999). But describing that relation requires undoing certain mechanistic assumptions about causality at the foundations of science and mathematics.

The second source for the framework, PAR, contrasts the highly theoretical approach of relational biology because PAR is an empirical framework for complex systems analysis and management in the social sciences. Relational causality turns out to be very much like a PAR cycle, although there was no connection between these developments. PAR developed empirically and demonstrated broad applicability in the social sciences, but is in need of a theoretical foundation for its broader application (Greenwood & Levin, 2006; Koshy, 2005; Khemmis, McTaggart, & Nixon, 2014; Sankaran, Dick, Passfield, & Swepson, 2001).

Nevertheless, many similar four-cause frameworks exist independently across disciplines, and it is surprising that we have not managed to "connect the dots" to see their commonality. Here we attempt to do that—to describe a general framework for understanding and interacting with complex systems.

In addition to these two sources, the framework presented here has deep historical roots. The ontology of four-cause frameworks reaches far back into antiquity. For a good account of its origin in Western Aristotelian philosophy see Lowe (2006). For deeper understanding of its origins, delve into Eastern Vedic philosophy (Loy, 1997). It is apparent between these two histories that something was lost along the way to modern times. It seems that we traded a whole view of causation for a mechanistic view, one that separated observers from observed, subjects from objects, humans from nature, science from religion, and so on. The term *law* became synonymous with "universal law," whereas post-modern science is moving toward "model-dependent" or "context-dependent" law.[3]

[3] In mathematics this condition is known as "impredicativity," meaning that a system's laws are not fully "predicated" on those of the general environment, but are at least partially determined within the system being studied.

Although prior science has clearly shown the value of deterministic models, it has also revealed their limitations. Roughly speaking, mechanisms have singular noncomplex models in contrast to complex relations that allow for emergence of novelty and even life. Despite positivistic hopes of explaining all systems within a single formal system, or the counterpoint of looking at cognitive and social construction, neither seems true alone but both may be true together. In other words, we must accept a notion of *complementarity*. We can observe that systems posing the greatest need and challenge for understanding and management today, including ourselves, are what we could call "complex" because they contain both general and self-determined formalities. Presently, there is no accepted theory that combines the two, although many instrumental combinations and coupled models are employed in practice.

To accept a theory is one thing, but scientific work demands that theory be formalized in mathematical language, which allows it to be analytically descriptive and synthetically prescriptive. In particular, we want analysis and synthesis to commute or merge. Mechanistic theory has been so successful largely because it accomplishes that commutation, but it does so for only a classical (mechanical) sub-set of reality. Being a partial analysis, its synthetic possibilities are also partial. But, for complex systems, the researcher needs a way to decompose systems into whole units that, when re-assembled, will not lose important systemic properties of the whole (Rosen, 2003).

Various ideas of whole causal structures have been proposed in the system sciences although there has been little success in integrating them. Nevertheless, some form of unity is necessarily implied by the concept of a system. While we will use the terms *whole* and *holistic*, we mean the latter because a completely whole system that is not also a fraction of something else is an analytical idealization—a perfect identity that is technically isolated from the universe. *Holistic* thus refers to having whole causal cycles in the system, while also being able to interact through partial relations with other systems. That was Arthur Koestler's concept when he introduced the term "holon" (Koestler, 1970, p. 57)—both "part and whole" at the same time.

It is important for progress that the systems sciences adopt a general framework that reaches beyond previous limits to allow for constructive processes (Funtowicz & Ravetz, 1993; Rosen, 1999). And yet, it is also important for integrity that science remains consistent with classical modes of understanding that have proven valid and correspond with the indispensable language of our senses (Schlosshauer & Camilleri, 2011). Accordingly, the framework presented here represents an *integral* philosophy within an expanded scientific worldview. The more general case seems to be that mechanisms are context-dependent and construction of observer contexts is event-dependent, leading to a principle of self-similar holism and complementary determination. Within that relation, interactions are like agreements that form common contexts, whereas independent contexts account for complexity.

Frameworks in General

We can take it as a requirement for a book about systems research that if one proposes an exemplary framework it should be *rigorous*, if not in some viable sense *scientific*. It should respect ontological and epistemological principles and follow a defensible logic that is justified at some foundational level in mathematical philosophy, arguably the common language of science. In this case that requirement necessarily takes us to the most general level, the logic of categories and causalities. That arena has been heavily debated since Aristotle's famous discourses on those subjects (Barnes, 1984). Indeed, at this level, a fundamental way to frame reality is conceived. In doing that, modern science took its shape by choosing and selecting certain causes calling them *real* while rejecting others. Revisiting those choices is necessary if we are to reframe our worldview more generally and systemically to account for phenomena that could not be explained in the previous way.[4]

Frameworks are commonly adopted as heuristic ways of organizing a practice or study to learn and/or problem-solve. They may be ad hoc or, more recently, algorithm-based optimizations (Lee & Geem, 2005). Our framework, based upon relational biology and PAR, begins with general principles attributed to a supposed logic of natural relations, including human experience. There is no general requirement of frameworks, of course, that they should be *natural*, and studies routinely devise arbitrary ways of looking at problems. It is appropriate, for example, to develop a framework around policy or client drivers, or various other qualities of desired outcomes on a purely instrumental basis. However, if the framework we choose is general in its reference to nature *writ large*, it should be consonant with all of these cases. Furthermore, if it is applied even retrospectively, it should be able to add value to a study or practice, under the assumption that natural organization (which, the framework presumes to be real) is more likely to give us an appropriate model. This view assumes that our concept of nature is in some sense valid, thus acting in this manner also serves as a test of the framework's general validity.

The framework presented here answers the need for an analysis that allows for the most complex condition of a system, where contextual and dynamical causes have equal freedom. That is, we want to be able to analyze the *organization* of a system in terms of relations between context (e.g., dispositions) and actualizations (e.g., dynamics). It is a matter of empirical science to decide which aspects of a given system have been reduced to one or the other, and thus which aspects of the framework can be simplified. This follows a general rule in science to not classify too early.

[4] The reader may notice that we are using the idea of framework in much the same way as worldview, yet a mathematically explicit worldview.

Relational Holon Framework

Figure 2.1 is a graphical representation of the relational *holon*—the theoretical framework that we propose for systems research. Ontologically, it is a complementarity between measurable aspects of a system—the actualized[5] aspect, A, with solid arrows, and the contextualized aspect, C, with dashed arrows—made explicit as a whole by reference to Aristotle's four causes (Falcon, 2012). Aristotle's causes are considered *metaphysics*, in addition to substance and identity, which are concepts of understanding the fundamental nature of the world. Aristotle's four causes are material, formal, efficient, and final. Recall that a phenomenon's material cause is its physical properties; its formal cause is its structure or design; its efficient cause is its agent for being; and its final cause is its purpose for being. In Fig. 2.1 these four causes are labeled in the four quadrants of the relational holon. The cycle of causes enable structure (*s*) and function (*f*) epistemology. In the next section of this chapter, we will show its relation to PAR, which has essentially the same structure. The arrow and symbol conventions are explained later in this chapter, in the section, "Using the PAR Holon Framework."

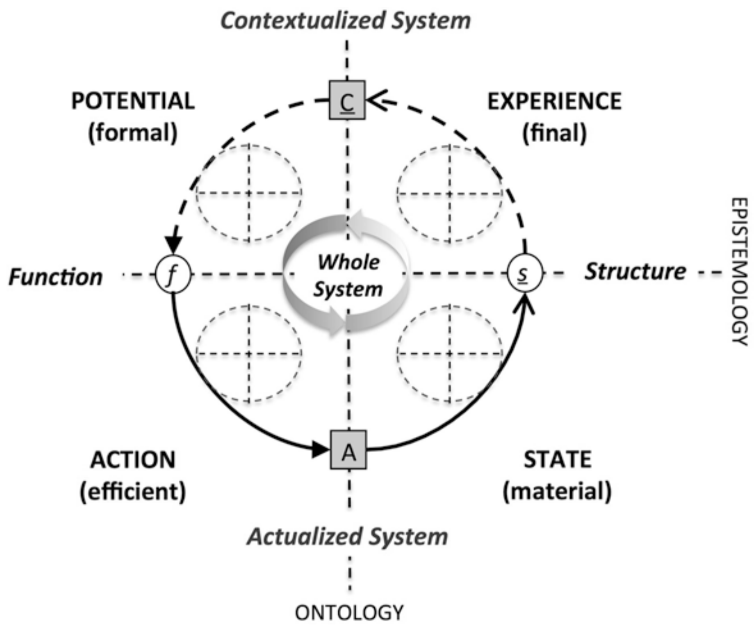

Fig. 2.1 Relational holon

[5] The term "actualized" is used instead of the more common term in relational biology, "realized," because with the introduction of the contextual category, both interactive and latent aspects are considered "real."

Holarchical organization, like that found in fractals, is implied by the four sub-holons in each of the quadrants of the diagram. These sub-holons can replace each quadrant (either as internal sub-units or external super-units) at any level. In other words, if the main cycle represents a given system, each causal aspect of that system is explained by another similarly holistic cycle; then the two cycles are said to be "closed" within one of these quadrants. The holon can thus be composed and decomposed in self-similar models.[6]

An important aspect of the diagram is that it relates *causality* and *inference* giving an explicit representation of Aristotle's concepts of "cause" and "explanation" (Falcon, 2012). We will show how this schema can be used as a consistent method of analyzing whole systems in terms of whole systems.

While providing a holistic analytical method for complex systems, it is apparent that this relational holon framework also represents a new scientific worldview. Interesting as that is, most systems researchers are concerned with relevance. It is for that reason that we note how extensively this causal structure appears to be empirically confirmed in many disciplines and cases, each with its own interpretation of the archetypical quadrants and their combinations as categories of entailment and relation. We will review the worldview implications and some examples of the framework in use.

PAR Holon Framework

The first, and perhaps most important, framework we should examine is used in PAR (Chapter 5). The relational framework represents a theory of natural causation, while PAR is an empirically derived practice that works the same way through human agency. PAR is a method of interactive or participatory research and social change. It is primarily goal directed: to intervene in a system and alter it in some way, or to study how systems change. The PAR cycle shares the same basic causal organization with the modeling relation discussed above, typically expressed as a cycle of Planning, Acting, Observing, and Reflecting.

The correspondence of the PAR cycle with Aristotle's causes is obvious when both are viewed as a cycle in which material ends become final exemplars:

PAR		**Aristotle**
Reflect	=	*Final*
Plan	=	*Formal*
Act	=	*Efficient*
Observe	=	*Material*

[6] A holarchy is thus an invertible hierarchy of inclusive wholes.

Any of these four agencies may set up another cycle. Figure 2.2 shows a typical, iterative PAR cycle where new cycles result from action and each cycle is identified by new observations. Hence, it characterizes an action research cycle. Similar iterative loops can occur for observing, reflecting, or planning. Participatory research, or intervention through the development of new information, might be best characterized by iteration based upon observation and interaction. Similarly, planning and visionary cycles can be described. The difference is in which quadrant one iterates. All four aspects are always present in all iterations, but the point of bifurcation establishes a researcher's intervention point, which identifies the program or what kind of intervention the researcher is applying (one of the four possible decompositions of Fig. 2.1). Through this, we can see that PAR analysis is enhanced by understanding the nature of the holon and its logical implications. In the following, we explore more possibilities.

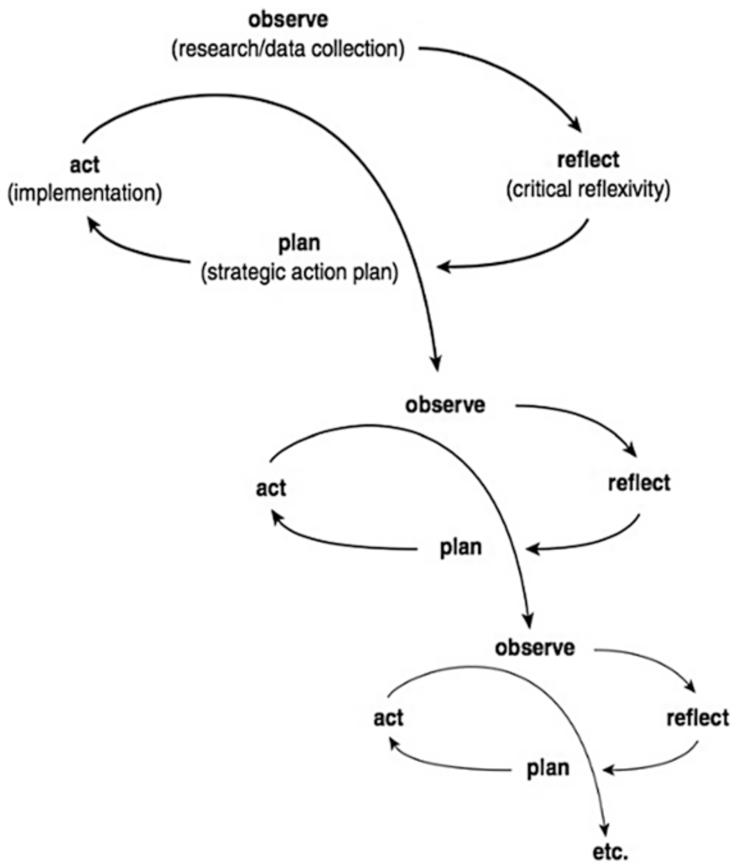

Fig. 2.2 Cycles in action research (O'Leary, 2004, p. 141)

The common PAR quadrant labels (Reflect, Plan, Act, and Observe) are applicable in cognitive/social cycles, but they are also instances of more general archetypal causalities (Fig. 2.3), suggesting a worldview of agent-like organization at the root of complexity and life, where the basic relation can be taken as a fundamental unit of natural analysis. Thus, as researchers, we are observing the same kind of organizational system by which we are conducting the observation. We do not need to assume that what nature is doing is, in principle, any different from what we are doing. In Rosen's (1990) view, assuming the same organization is the essence of true modeling in which models should be entailed (i.e., organized) like the system they model (R. Rosen, 1991). However, this framework does not insist on that correspondence; at a given level it can also relate simulations and analogies.

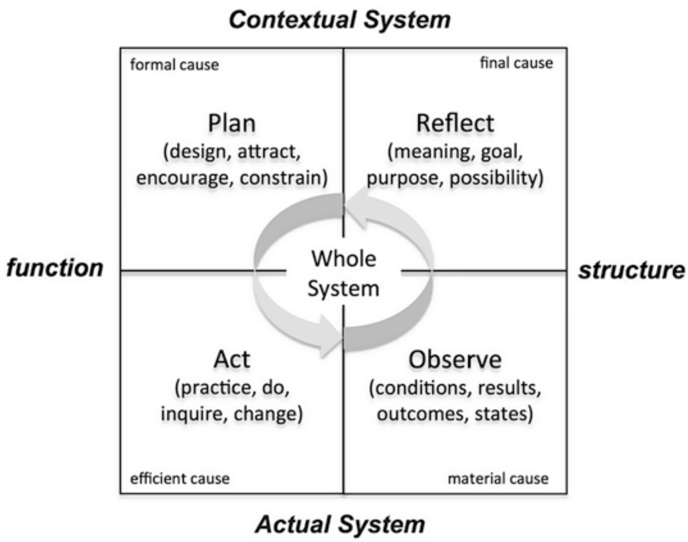

Fig. 2.3 PAR Holon Framework

Now, a brief, intuitive explanation of the four quadrants is important, not because there is anything difficult about it, but because we have not been trained to think this way.

Observe

Beginning with the lower-right quadrant in Fig. 2.3 we, as researchers, have sensory objects of perception—what we can observe. As we now know, observation is an interaction which can affect the object being observed, known in science as the *observer effect* (not to be confused with Heisenberg's uncertainty principle identified in 1927). Generally, we can say that any interaction is like an observation in that it establishes or abstracts a state of the object. Hence, this quadrant explains things in terms of what can be measured about them and the terms of measurement for the system.

Act

If we ask, thinking inductively, what governs the measurements we might receive, we reverse the cycle to the lower-left quadrant, which is action. It is action, Aristotle's efficient cause, which explains the occurrence or abstraction of states within a system; that is, action in nature and the action of observing itself. In fact, these two seem to be in a competition, where less frequent observations than natural interactions will reveal uncertainty and, vice versa, relatively frequent interactions establish mechanisms.

Plan

Continuing to reason and moving backwards around the cycle, we ask what explains the occurrence of efficient agents or forces. In this case, we arrive in the upper-left quadrant where formal boundary conditions or potentials for existence regulate the amplitude or scope of efficient causes. This is Aristotle's formal cause (although there has been much confusion about its position in the hierarchy). A very simple example in biology is niche dynamics, where the niche acts as a potential for existence, constraining, and regulating dynamic niche actualization. An example in physics is the curvature of space–time and the various constants we typically assume are absolute until we find cases where they vary (as in relativity). This quadrant is the expression of a modeling context or the conditioning in a social situation afforded by the character of the gathering, room, building, art, country, and so forth; all of which *culture* or *inform* what is thus encouraged or discouraged to happen in the discrete world of behaviors, also known as norms.

Reflect

Continuing, we can ask what explains such formative potentials. This takes us to the upper-right quadrant where we find the historical effect of previous configurations, which might be analogous to systemic experience. This is the effect of exemplars, visions, ideas, intuitions. They are as physical as any of the other quadrants, and far more intuitive than has been assumed in the many rejections of *final cause*. The evolution of organisms is predicated on previous organisms serving as exemplars for the next, via contextual encoding (variation and selection). A new invention is predicated on some vision of an old one. A recipe for biscuits probably came from some previous example. Written narratives in books may be based upon folklore. If we go on to ask what explains this quadrant, we arrive back at objects actualized before. As thinking beings we may find it easier to understand the cycle in such reverse direction, which as Aristotle saw, is the answer to "why" questions.

Cycles of Entailment

In both actual and contextual halves of the holon diagram in Fig. 2.1, we suppose causality (or inference) can be mapped as a mathematical entailment. Entailments are explained in detail in Chapter 4. Basically they are very flexible causal propositions such as the reason for some change. For example, what compels or motivates action and/or direction? An efficient entailment in the actual system is a dynamic change. But the mystery involved in the holon cycle exists in the contextual entailment, which is not commonly graphed, even in relational theory.[7] The problem is basic: We accept the concept of a *force* resulting in a new state (this was once considered "spooky action at a distance"), but do we understand how a state can establish a new force? Or, as Schrödinger described the problem, which he considered fundamental to life, how does an "inertial object" become a "gravitational object" (i.e., an *agent;* R. Rosen, 1999; Schrödinger, 1955)? Nothing in modern science explains it, except that natural objects clearly do both.

Those willing to grapple with this thorny issue tend to decide between two possible answers. In one sense we can say that there are no objects as such, they are all part of a whole system with all four aspects; so naturally, the state is correlated with and *carries* a function. But there is a more analytical answer: that a structure, when placed into a context, will induce a function *from the context*, just like a grain of sand (or other perturbation) placed in an oyster induces functions that produce a pearl. Or, a tool will have different uses in the kitchen than in the shop. Generally speaking, objects impregnate context and it is from that *inverse (or converse)* of the efficient map—the *contextual or final entailment*—that we get new functions. This principle is not restricted to living or cognitive systems, as we see in the quantum and cosmological world, where there is a two-way relation between interactions and the coordinate space in which they occur. This different kind of entailment will be discussed in Chapter 4.

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[7] It is technically defined as an "inverse entailment."

Describing Organization in Systems

With this cyclical-cause view of a system expressed as entailment, it is clear that the contextual causes comprise a new area of research that has been difficult to introduce and explore. It appears today in concepts like "dispositions" (Mumford, 2003); the idea of "affordances" (Chemero, 2003); in a wide scope of literature about "control theory" in cybernetics (Åström, 2012; Chapin et al., 1997; Corning, 2001); the subject of "boundary conditions" or the "boundary value problem" (Cziko, 2000; Kelso, 1995; Wiens, Crawford, & Gosz, 1985); and "potential theory" and "function spaces" (Adams & Hedberg, 2012; Doob, 1984; Triebel, 2010), although most treatments of the latter tend to be somewhat nongeneric in that they are restricted to value limits of differential equations. Much of this discussion comes under the heading of *self-organization* (Ashby, 1947; see also Kauffman, 1995), in which order arises from local interaction between parts of a system and involves *causal loops* or cycles.

A cycle of causes can also be reduced to simpler cases, that is, to mechanisms, by assuming a fixed formal context (a complete set of natural laws). Or, it can be focused on contextual (i.e., subjective or otherwise nonlocal) qualities that may support constructive processes as experienced (Chalmers, 1996; Hameroff, Kaszniak, & Chalmers, 1999; Searle, 1992). We should understand that this latter case, outside of its relation with actualizations, is also a reduction. It has been problematic to many natural scientists for this reason: it seems to represent *form* without *substance* (like an ecological niche for bears, with no bears; or goals and plans not yet implemented in the world). However, in both cases, that is the reduction to mechanisms or niche-like affordances, the complementary domain remains theoretically present; it is simply ignored as adding no important variation. Furthermore, the relation between context and actual need not be immediate; the contextual influence (to reveal where we are going and call it a "model") only sets in motion the dynamics for its realization in a spatio-temporal domain. The framework is thus inclusive and consistent with these opposite views; yet, it also allows a study of how they may be related.

For example, we can imagine future technology without yet knowing how to build it. We can describe an existing object or its behavior without the complexity of explaining its existence. But neither one of those views alone characterizes a complete system. They are *fractions* of a system (R. Rosen, 1978), and most of modern science—from natural to social—has chosen between these fractional views, focusing either on measured or experienced realities. Scientific unity, an elusive goal, depends on what aspect of a system is to be objectified (natural science) or represented (social science).

The focus can be on a "third" alternative: *objectifying relations* between context and action. Needless to say, there can be a great deal of controversy about this view, but we are obliged to adopt a holistic view by our experience with the natural and human world, which hints of such organization. Just as physicists were compelled to accept uncertainty over a 100 years ago, today we must grapple with complexity. While it is extremely important that the framework we propose follows the mathematical logic of causal order, it is second to its correspondence with referents in nature. In other words, we put the science first and understand mathematics as a language of science.

Anticipation

We can now ask, "In what way is it 'natural'?" Inspection quickly reveals that the two sides of a modeling relation represent models of past and future. Everything that we call *actual* has already occurred, and everything we represent in an un-actualized model is yet to occur. Traditional science has given primacy to models of the past, assuming they are generally predictive of the future. Here we do not dispense with that view as one option, but broaden the schema to allow for systems more driven by models of a possible future. The information relations (encoding and decoding) thus represent *now*; a concept that is not commonly formalized. *Now* occurs in the relation between past and future—the acts of *being and becoming*. Arguably, *now* is all there really is in nature, except for models of past and future, both of which are encoded in the present. The framework succeeds in being natural in the sense of representing an active present situated between models of past and future.

Previously, scientists have not thought of *participation* (less so, *anticipation*) as a general principle; and consequently, our traditional view of nature from modern science does not include it. But it should be clear that we cannot get away with formalizing participation strictly for the case of human consciousness, because the principle itself was discovered rather indisputably at the foundations of physics, by far predating not only humans but all life that is even conceivable. Relational theory allows for the phenomenon of participation and its living consequence, "anticipation"—acting in relation to a future condition that is represented in some way in the present (Nadin, 2010; J. Rosen & Kineman, 2004; R. Rosen, 2012; see also literature on purposeful or purposive systems, Ackoff & Emery, 1972; Giampietro, Allen, & Mayumi, 2006). To the extent that a system actualizes its anticipations, which have the effect of models, it is a participant in a greater system that must, in some way, incorporate its corresponding behavior. Thus anticipations become reality.

The Importance of Context

Of course, the question we must address is how the framework can help systems research. As such, it represents a qualitative approach within which researchers may consider the organization of a system and therefore the regulation of quantitative processes by contextual conditions. It does not directly indicate what those quantitative processes are; that is a separate matter of empirical study. Yet, it allows us to consider what kind of topological space they can occur in, and by what means their determinations affect the topological space (contextual order). Thus, a researcher can analyze the relational organization of context and dynamics using available models for each. For example, physical and chemical laws at the molecular level may be involved in protein folding, but nothing in those laws can account for the contextual conditions ("top-down causation") that make protein folding and activation possible in the first place (Dill & MacCallum, 2012); yet, those conditions are established by the system. Another example entails Newton's laws of motion, which may apply in inertial frames of reference, but they do not account for scale change (relativity) under uniform motion; and yet, local dynamics establishes the relativistic context (Einstein, 1924). Similarly, the dynamics of co-workers in a corporation may depend on the values and designs that characterize the corporation and to which those dynamics may or may not contribute (i.e., a possible basis for analyzing unhealthy and healthy organizations; Cochran, 2015).

As Mumford (2003) and Chemero (2003) emphasized, dispositions and affordances—the effects of context—are everywhere in science, in all disciplines. They are nature's tendencies. The first thing we must realize in framing our approach to complex systems is that we cannot describe dispositions with the same formalism used to describe dynamics, except in special cases. These complementary aspects of a system must be represented in their own right, co-informing each other.

By considering contextual effects of a system as naturally related and constructed with dynamical behaviors in the system, the framework draws attention to *system wholeness* that may be maintained or disrupted, allowing a system to sustain its functions or to exhibit pathologies (Troncale, 2006). By understanding the organization of a system we can explore the probability or improbability of certain behaviors; not just as a result of predictable development but also resulting from emergence of new possibilities and new systems from new contextual relations. Focused application of the framework as an analytical approach can help reveal how qualitative properties of a system act to guide or direct dynamics and how dynamics contribute to higher system qualities.

For example, to some degree the framework is compatible with current trends in physics toward "model-dependent reality" (Hawking & Mlodinow, 2010), except for the "shut up and calculate" ethic (Mermin, 1989, p. 9) that tends to exclude realistic models. This trend also appears in dialectical constructivism in biology (Levins & Lewontin, 1985), and policy analysis (Morçöl, 2002; Patton, Sawicki, & Clark, 2015). Dialectical methods tend to be alternatives to classical views in physical science and ideas like sociobiological or genetic determinism (Peters, 2014; Wilson, 2000). This dichotomy is roughly the difference between strong pragmatism (denying more than instrumental "usefulness" of ideas) and strong realism (belief in positive confirmation); or put in the grossest generalization, one sees unity to be an illusion and the other sees plurality to be the illusion (Schrödinger & Hastings, 1964). Similar dichotomies appear also in opposing views of free will, and the question of whether nature itself can be said to have the quality of mind. We need a way to bridge these gaps (Venkatesh et al., 2013; Wiek, Farioli, Fukushi, & Yarime, 2012) that seems suitable for "new" or "post-normal" science (Funtowicz & Ravetz, 1993; R. Rosen, 1999; Schrödinger, 2012).

In practice, it may be that both views tend to incorporate aspects of each other (Martin, 2007). For example the idea that novelty implies a constructive purpose was famously challenged in an analogy to architectural "spandrels" that appear inadvertently between supports in cathedrals and provide accidental space for art (Gould & Lewontin, 1979). The point was that emergent opportunity can be a consequence of necessities. The advent of mixed methods research (Halcomb & Hickman, 2015; Johnson & Onwuegbuzie, 2004; Johnson, Onwuegbuzie, & Turner, 2007) is one attempt to reconcile these differences, as perhaps is critical realism (Zachariadis, Scott, & Barrett, 2013), social practice theory (Reckwitz, 2002), process philosophy (Gare, 2011; Ulanowicz & Kauffman, 2009), and a number of other paradigms that have emerged with the aim of providing a post-positivist integration (as opposed to a complete substitution) for comprehending systems.

The problem has been that unqualified realism can become dogmatic, but its strength is in its method of testing for what may be considered the best model of nature. We can accept that a single best model may not be found, and yet, it still does not follow that all models are thus theoretically equal. Similarly, pragmatism can suffer from testing in terms of human expectations alone, whereas it does not need to exclude the idea that nature can establish its own contextual realities and produce mechanisms that positivistic methods reveal. The fact that these two approaches each seem to produce valid results further emphasizes that construction is a natural process; that after all, humans came out of nature, not into it; so our own internal models must in some sense *know* nature.

As a result of these assumptions, natural scientists might miss the point that natural encoding occurs contextually; that is, every measurable event must have a formal domain that specifies the organization of measurements—how they are entailed in a metrical space. Dialectical practitioners may miss the point that social construction would be worthless without natural encoding; in other words, human concepts cannot be useful for interacting with nature if they are not, in some way, derived from it. In defense of both views, the realistic search for natural models has been the most effective way to test our assumptions about nature, but only given that it is combined with the constructive freedom to explore new models and new foundations.

Modeling Relations

The holon framework presented in Fig. 2.1 can be directly related to Rosen's concept of a "modeling relation." That modeling relation, shown in Fig. 2.4, is the vehicle that takes us out of our normal way of thinking about nature and science.

The modeling relation is between a "natural system" and a "formal system" that involves encoding and decoding the formal system in a way that agrees with the natural system (R. Rosen, 1990, 1991).

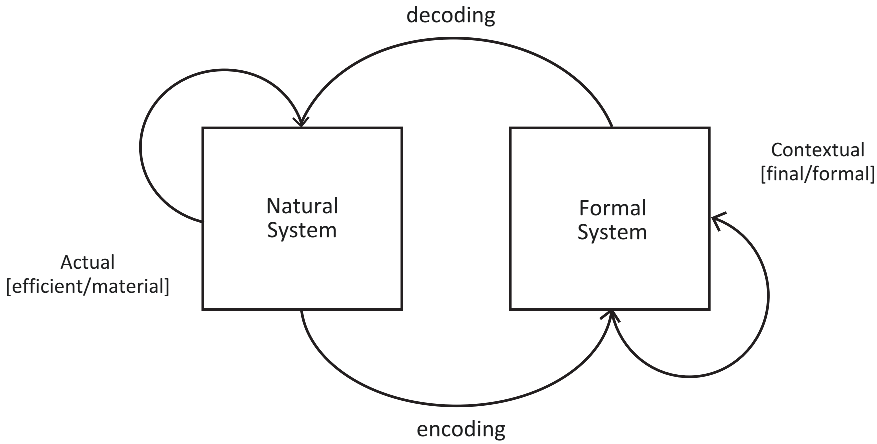


Fig. 2.4 The modeling relation

Rosen also demonstrated that both sides of the relation could be natural systems (modeling each other), or they could both be formal systems (as with models within mathematics itself). The curious fact, however, is that the encoding and decoding operations are *not part of either system*; they are, essentially, what is done by the researcher. If we remain with that view, we can think of both the model and the natural system as containing analogous efficient causes, and the researcher is the one who compares them (more or less by analogy). But then who or what is encoding a natural model, which Rosen demonstrated is characteristic of all life? To address this question, we need to consider the possibility of modeling a complex or living system and the possibility of using a complex model to do that. As shown in Fig. 2.5, a Nested Modeling Relation, it is a modeling relation between modeling relations, potentially without end. Rosen was able to state another property of complexity on this basis in that a complex system has no "largest model." If a system does have a largest model (one that explains everything), then it is a mechanism (as in classical science).

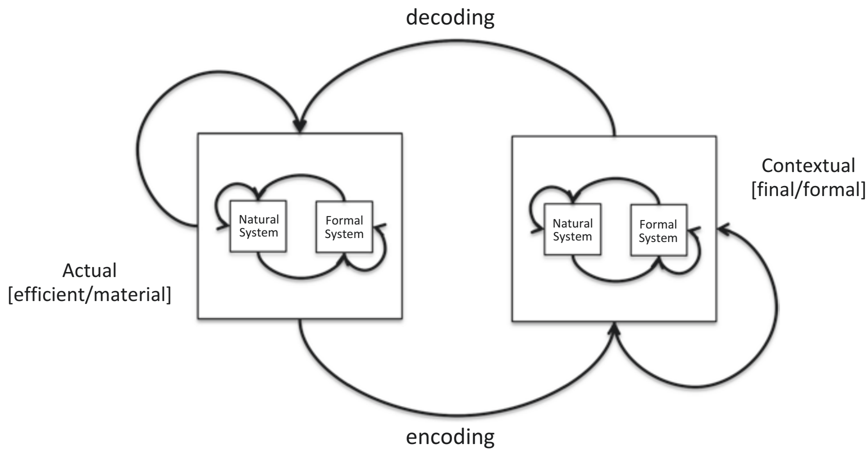


Fig. 2.5 Nested modeling relation

This diagram suggests a possible solution to the problem because it has embedded the coding relations of one level into the modeling relation of another. Unfortunately, it comes at the cost of adding complex relations because, as soon as there is an internal model generated by the system being studied, there is a system-dependency (impredicativity). We lose the ability of modeling relations to commute precisely, which means that the path of entailments and coding relations through the model gives the same results as a study of the system itself. This kind of infinite regress is a problem for science, because it compounds impredicativities rather than analyzing them. This regress prompts the next question, "Is there a way to preserve the uniqueness of a system–model relation while still considering internal models?" Indeed there is, but it comes at another cost.

Modeling Relations: Contextual Entailment

We must consider a differently entailed contextual domain of reality. Instead of considering the relation that exists between material systems (model and modeled), we need to consider the relation that exists between the material system and the coding processes themselves, where the translation between efficient categories takes place. By encoding and decoding we mean a translation from one side to the other, preserving the entailment structure of each (meaning to preserve the causal organization of each system as they are compared). If that translation is between two efficient systems, as might be supposed, then the translation must involve an intermediate inversion—an inverse entailment, which is what we call a *contextual entailment*.

We can now consider a much more meaningful modeling relation that underlies the obvious analogy between the behavior of a model and the behavior of what it models. It is possible to consider the modeling context as causal in its own right; that which produces the functions that generate and/or operate the system. For the sake of distinguishing them, this might be called the *fundamental modeling relation* as opposed to a *realized modeling relation, which is more like an analogy*. The fundamental relation is between a system and its laws, as is the relational holon.

This result is an interpretation of the modeling relation diagram by which it becomes a very powerful analytical tool. Figures 2.4 and 2.5 remain the same but we now understand the right side of each relation to be an inverse entailment—the inference of a function itself, rather than a surrogate material system built from such inferences.

The question arises as to what can be done with an inverse entailment map. To date, it has been overlooked as being "inaccessible," having to do with the inferential abilities normally associated with consciousness (Merlin, 2001). To some degree it is already referenced in the category theory logic, but not commonly examined as proposed here. Efficient entailments result in measurable states, but inverse efficient entailments—final entailments—result in functions.

But if encodings and decodings preserve homomorphic entailment structures (as they are supposed to), then there must be logic which can be applied to the contextual entailments to achieve that. This case is clear with regard to the fact, mentioned earlier, that mathematics is replete with models of mathematics. In fact, contextual logic can tell us a great deal about the qualities and organizational aspects of a system. Far from being inaccessible, contextual analysis opens up new possibilities for complex system analysis.

It is clear from category theory that the encoding and decoding relations between categories[8] are not the same as entailments (causal maps) within categories. They convey and preserve information about the entailment rules ("mathematical structure" as defined in category theory) in each category and translating that information into the other category. Perhaps it is not too difficult to see that the logic of what occurs in the world must be attributed to the contextual category. This is where we get boundary conditions on natural phenomena (the supposed "natural laws" which specify what *can* happen and *how*). The problem is, these laws are neither known, except by experiment, nor are the boundary conditions known on the laws. All that information is part of the formal nature of a contextual entailment, including discoveries like quantum uncertainty or (if it is true) vacuum energy.

Presently, this type of information is considered a "black box" that few want to look into except to find mechanistic formalisms. But the four-cause holon cycle indicates that what is in that box is itself related to its complementary category—the world of phenomena. In that case, what appears to be unknowable, sometimes referred to as "law without law" (Wheeler, 1981, p. 182), may have some primitive logic associated with the inverse (final) entailment mapping and its relation to actual phenomena. Exploring that logic will reveal organizational aspects about whatever system is being studied that could not be seen before. In fact, science has already peeked into the box in the case of quantum probability, relativity, niche models, and affordances.

Modeling Relations: Actualized Entailment

Now, it is important to consider the different, complementary nature of these two categories. The entailments we describe on the actualized side are about phenomena in a "local" world with coordinates where measurement is possible. It lends itself to efficient (dynamical) description. The entailments on the contextual side are about models, which in a meaningful sense are about potentials and possibilities for existence, which, with regard to the world we define in terms of space and time, is *nonlocal*. It becomes generative or behavioral with respect to actualizations of its models in material systems.

The descriptive methods for actual versus contextual categories are different. Efficient entailments occur in a world of discrete events and objects (which has specific formal conditions), whereas final entailments are in a nonexclusive space that does not not have locality or temporality directly. A simple optimum in temperature, for example, has no locality in space and time as such, except through

[8] Technically, in category theory, these are "functor" relations, explained in Chapter 4.

actual temperature distribution. Each of these specifications thus varies independently and according to different rules. Thus, indeed, we are describing a complementarity. As Alfred Korzybski famously wrote, “The map is not the territory” (Korzybski, 1933, p. 750).

There are several examples in science. In quantum theory, it is necessary to consider the nonlocal *quantum vacuum*, which has tremendous potential energy. The same need appears in cosmology in the *cosmic void* or *dark energy*, which is an unmeasurable existence needed to account for the expansion. In human and social systems there is the question of goals, plans, designs, and many aspects of a conscious mind. These concepts are not integrated as each postulates nonlocal contextual domains. Throughout the history of science and humanity, philosophers have considered the idea of such a domain in terms of *aether* or *plenum* (Greek and Latin terms for the substance of space itself), Kant’s *noumenon* (as potential for phenomenon[9]), and even various kinds of “fifth-essence” unity. In Indian Vedic philosophy it is known as *akasa*, which is like a natural memory of phenomena associated with an informational existence, sometimes called “nonexistence” that together with “existence” makes a whole.

Such considerations were excluded from early Western science in order to focus on mechanisms, holding the contextual side of all relations (in nature or in science) constant. Thus, they were really just overlooking variation of final and formal cause, whereas the existence of those domains had to be acknowledged, albeit prior to science.

Hence, the formal domain itself is entirely present in science as natural law reflected in our formalisms, implicating a corresponding order in nature. Today, there is tacit agreement that there must be a model-like complement of the phenomenal domain that is responsible for complexity (Hawking & Mlodinow, 2010; Henry, 2005). We do not want to get lost in the immense implications and history of this view, but it is important for the reader to realize that the framework is not a simple heuristic. It is appropriate in some cases but not others. If the framework is valid, it tells us something fundamental about nature, which is why it tells us something general about systems.

Holon and Modeling Relation as Semantic Relations

We have learned that the coding relations in the holon and modeling relation must be described as information relations. They translate between different kinds of entailment. For example, a scale model of a house might be similarly entailed as the eventual house. But the one cannot become the other, except by informing its construction through its meaning. So, they are semantic relations: encoding into an

[9] There have been various views of noumenon, but even Kant’s idea dismisses it by simultaneously overstating its reality (“the thing itself”) and then declaring it unknowable. Here it is nothing more than contextual potential for existence of phenomena, researchable through inference.

inferential model (context) and decoding into measurable phenomena. We can abandon the idea that they are in some sense "unnatural."

By this very elegant modeling relation, Rosen raised the question of information *in* nature, and implicitly, *mind* in nature (Penrose, 1994; R. Rosen, 1993; Wigner, 1981). This relation is further addressed in Chapter 4 and considers modeling approaches in science.

The two domains and four causes defined by a modeling relation are only analytically separate—that is, a system should be thought of as having all aspects, even if only one is apparent at a given time, place, or scale. So, we can use the modeling relation in multiple ways. It can represent one system that has these complementary aspects, or it can represent a relation between complementary aspects of two systems. Thus, it can define a systemic relation or a relation between systems and we can use it to look at relational closure as appropriate. This solution creates an infinitely holographic order (scalable and self-similar) comprising modeling relations *all the way up and all the way down* (see Fig. 2.5).

Ubiquitous Appearance of Four-Cause Frameworks

Where uncertainty or natural indeterminism (as one assumes) seems to rule, the mechanistic approach of the physical sciences does not seem to do well. It is clearly for a special kind of system that does not include the subjective influences normally attributed to agent-like (as opposed to law-like) complex processes. It also leaves out the living and human worlds about which we are ultimately concerned as individuals and as a society. Nevertheless, the machine metaphor is still routinely applied to living systems. Consequently, each discipline has had to invent its own framework for considering contextual causation. Following are examples indicative of their ubiquity and how the holon framework can be used to integrate them.

In current science and management practice, the four-quadrant framework can be seen in various forms:

- Environmental assessment (Kristensen, 2004),
- Integral ecology (Esbjorn-Hargens & Zimmerman, 2009),
- Adaptive assessment and management (Holling, 1978; Olsson, Folke, & Berkes, 2004),
- Sustainability science (de Vries, 2013),
- Learning organization (Örtenblad, 2004; Senge, 2006),
- Autopoiesis (Maturana & Varela, 1980),
- Vedic ecology (Kineman, 2005; Prime, 2002),
- Evolutionary learning (Walker, Cisneros, & Davies, 2012),
- Niche construction (Kylafis & Loreau, 2011; Odling-Smee, Laland, & Feldman, 2003),
- Time and cosmology (Masreliez, 2012; Smolin, 2014; Unger & Smolin, 2014),
- Holistic ontology (Checkland, 1988; Edwards, 2005; Koestler, 1970; Lowe, 2006),
- The mind-brain problem (R. Rosen, 1993),
- Second order (or new) cybernetics (von Foerster, 2003), and more.

Consider this example from environmental science: The "Drivers-Pressures-State-Impact-Responses" (DPSIR) framework (Fig. 2.6), which defines a cycle of social drivers and natural processes that are part of an environmental assessment (Kristensen, 2004). DPSIR is used extensively in environmental assessment and management. It was also adopted as official policy by the European Union (Atkins, Burdon, Elliott, & Gregory, 2011; Bell, 2012; Ness, Anderberg, & Olsson, 2010; Tscherning, Helming, Krippner, Sieber, & Gomez y Paloma, 2012).

The DPSIR framework is easily interpreted in terms of PAR Holon cycles. The usual representation, as shown in Fig. 2.6, is obviously confused about what to do with Response, how it is actually supposed to work except that it needs to interact with all the other elements. But response must also be organized in a natural way.

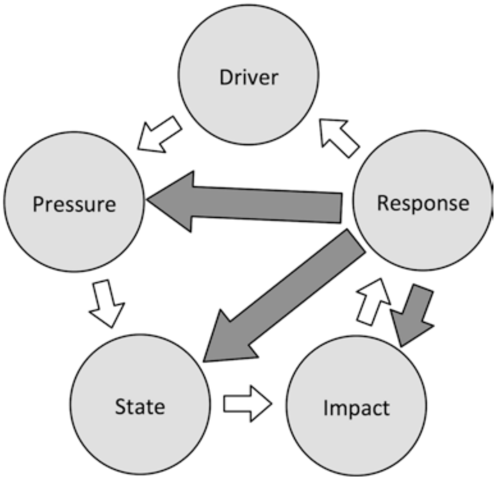


Fig. 2.6 DPSIR framework

When we realize that Response is another holon cycle, initiated when impacts are assessed (as tacitly implied by the small reverse arrow in Bell's diagram), the diagram can be redrawn in a way that is much more understandable and much more informative as a second order complex closure, shown as DSPI/R in Fig. 2.7, each cycle responding to the other with closure in the Impact/Response quadrants.[10] In other words, they are *closed to final cause*. In a sense, we can imagine that as a closure with each system's future. The assessed impact on the system's future is taken into a management context to design a plan to alter that trajectory. The holon view also emphasizes that the process should not stop with one Response, which itself can have unexpected impacts. The ecosystem changes introduced by management action thus close with the ecosystem context, from which there is another round resulting in impact from the management changes. Closure means the two

[10] They are not fully "closed" because besides this interaction each also has its own cycle that continues independently (management systems do have inertia!) and each can be influenced by other systems.

cycles exist together as a complex adaptive cycle as recommended in Holling's (1978) book, *Adaptive Assessment and Management*, but rarely implemented.

The DPSI/R example also shows how to use the worksheets (see Section "Appendix: Worksheets") for basic holon analysis. There are many subtleties of using this framework. For example, the Response cycle essentially replaces the Impact arrow in the Impact cycle; thus implying assessment of the impact and intervention in the Ecosystem contexts. The result is equivalent, but this double loop diagram is explicit about both cycles. Of course, it is arbitrary which cycle is drawn on the inside or outside, except to suggest a general convention of placing the genetic identity inside the behavioral identity.

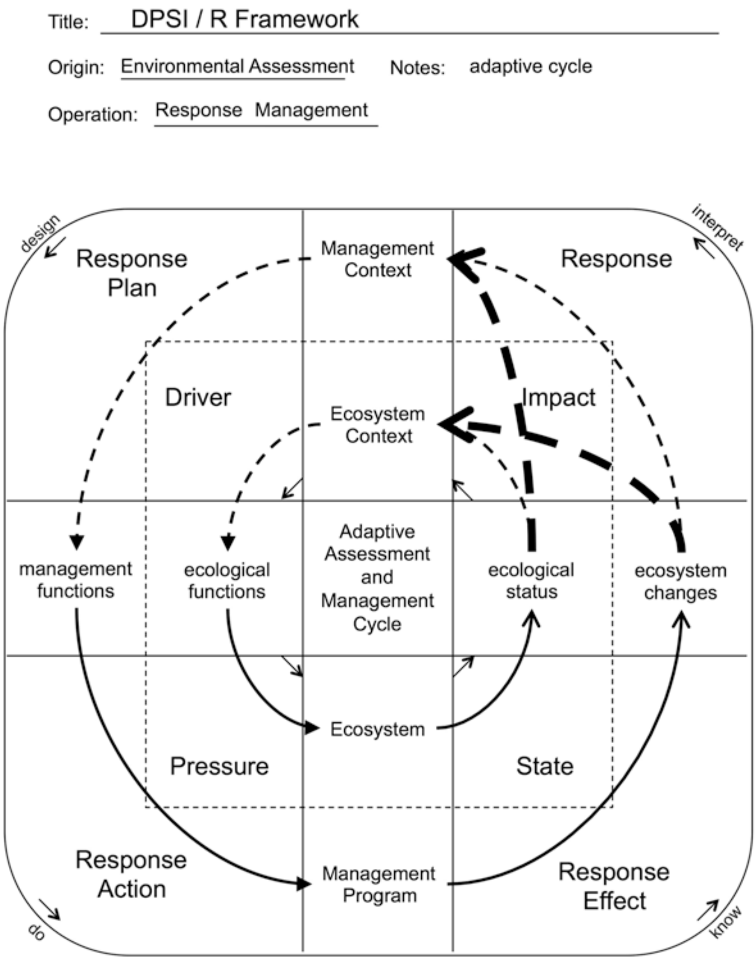


Fig. 2.7 DPSI/R holon worksheet

It is worth discussing this case a little more generically as a model of complex relations. Clearly, in this case, management models may not exist in the same formal domain as natural processes, which is the criterion stated earlier for complexity. Typically, this basic case of complexity will identify two very different kinds of systems, one that is about existence and one that is about behavior. Those two contexts are present for everything that exists and interacts; their formal models are generally not miscible (as with evolution and ecology, waves and particles). For an organic system, these two cycles can represent genotype and phenotype, in Chinese philosophy, also known as Yin and Yang.

Even in engineered systems it is clear that the goal of engineering design is to separate these two cycles as much as possible; one being the design/production cycle—the origin of the system, and the other being the operation/use cycle—the behavior of the system. In organisms, these run simultaneously; we are redesigning ourselves as we live. But that is the opposite of what we want machines to do, at least until we can guide their redesign. Our mechanistic view of nature in modern science has implied the same thing—separating origin (the big bang and absolute substance) from operation (dynamical laws of conservative reconfiguration). While that separation does appear in nature of its own accord, we are now confounded by the many cases where origin and behavior remain in relation—the case where complex relations (between original and operational causes) have been preserved by causal boundaries (which isolate phenomena from highly interactive domains).

As another example, Peter Senge's "Fifth Discipline" (or learning organization) defines a learning cycle in management that also relates these four causes and indicates a fifth level unity (Garratt, 1999; Örtenblad, 2004; Senge, 2006, 2014). The basic learning organization cycle can be easily shown in the PAR framework (Fig. 2.8). As such the learning organization attempts to be whole by defining each one of the quadrants and their fifth level unity as an identity cycle. But to the extent that it achieves a whole organization like a living organism, it will then have the same phenotype and genotype interactons with its environment—the world of competitors, customers, resources, and so forth. The internal organizational stability (its genetic identity) is thus necessary, but not sufficient without further analysis of the external relations (its behavioral identity).

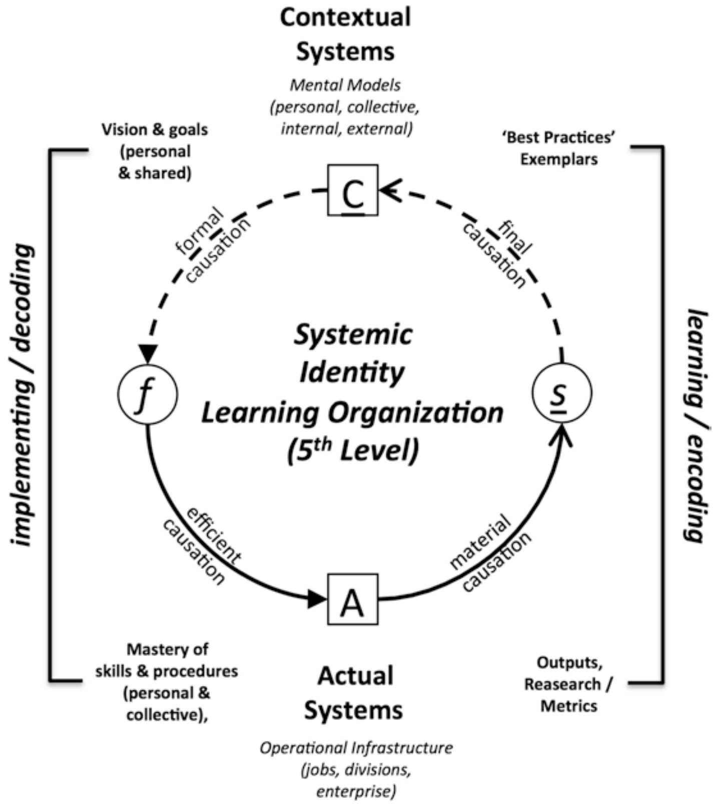


Fig. 2.8 Learning organization (as a holon)

For our purposes, it is unnecessary to review the many instances of similar four-cause frameworks in various disciplines; the point being that we have not connected them to develop a general theory. There have been some attempts, for example an almost lost theory of "quaternios" presented by Carl Jung (Jung, 2014; Stein, 2012), in which he proposed a very similar holon relation to explain "the archetype of the Self." Although set in a mystical theological context deriving from Kabbalah, alchemy, and Gnosticism, this work was meant to suggest a general science of wholeness and consciousness. The basic intuition corresponds with our framework. However, its ties with many interpretive schemas seem to confuse its general meaning. The interpretation Jung (2014) cites from Athanasius Kircher seems to correspond best. A more recent holon schema by Kenneth Wilber (Wilber, 2007) shows similar deep cultural and psychological insight. The best correspondence, however, still seems to be with more ancient concepts in the Vedas and Upanishads of India, from which many of these ideas may have descended with various modifications.

Ways of Using the PAR Holon Framework

Figure 2.9 shows the various ways that the PAR Holon Framework can be used by combining holons. The most primitive diagram is a system identity (Fig. 2.9, diagram A), which is a first order holon (meaning it contains one holon). This is also the basic framework view presented in Fig. 2.3, which gives the quadrant labels. Here we look at the four nodes of the diagram as: Context (C), *function (f)*, Actualization (A), and *structure (s)*, the system elements that are causally entailed by the four quadrant causalities discussed earlier. These are the ontological elements (C, A) and epistemological elements (*f, s*) of the system. The system identity, can also be represented by a label at the center of the holon (e.g., “house,” “Lake Erie,” “Fred,” etc.), recognizing that a single loop is an analytical idealization and in reality it has other relations.

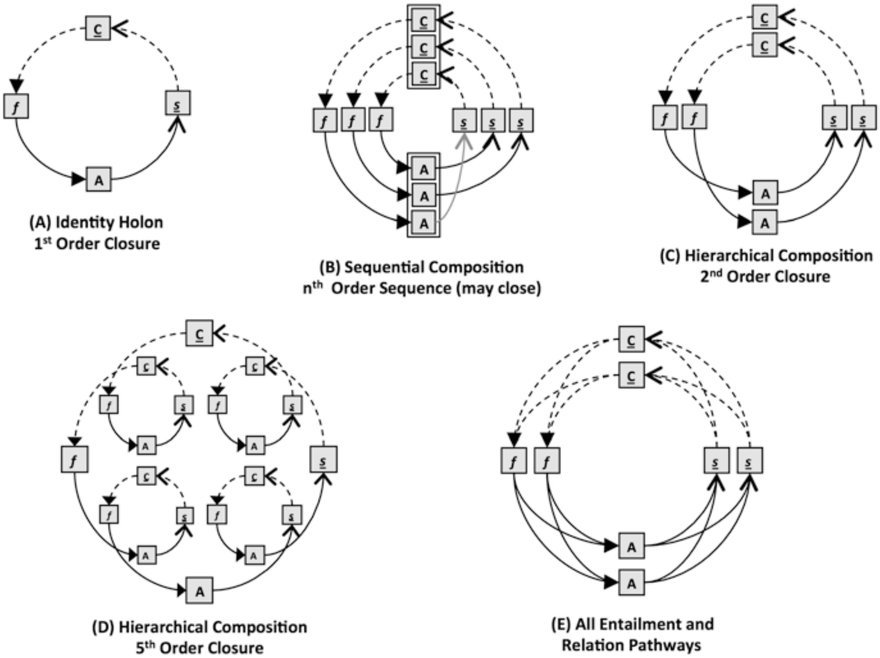


Fig. 2.9 Holon compositions

Holons can interact with other system holons in any of the four quadrants (Fig. 2.9, Diagram E), although the C-*f*-A-*s* order is always preserved. This system of analysis presumes, or defines, that order to be universal. If the order is not preserved the causal relations no longer have meaning, so it is as much a fact of the analytical system as it is a statement (or hypothesis) about nature’s organization. It is generally helpful to keep track of the identity loops as well, and one may choose a common letter identifier for all the nodes in a given system (in which case the letter format and highlighting can be used to keep track of its role). Contextual entailments are shown as a dashed line and actualized entailments are shown with a solid line. Formal and Efficient cause (decoding) have solid headed arrows, Material and Final Cause (encoding) have open headed arrows. The PAR Holon quadrant labels (causes) belong to the arrows entailing these elements.

With these simple conventions very intricate system diagrams can be drawn without losing track of sub-systems, identity relations, and interactive relations. It may be useful to think of these nodes as the *nouns* and the quadrant causes described earlier as the *verbs* in the holon syntax. The holon is therefore a language repeating a fundamental statement of systems: *A function applied to a behavioral system produces states that in turn alter the contextual boundaries of a system to establish new functions*. Everything about systems is assumed to be a more specific version of that story.

The typical spiral PAR cycle (shown in Fig. 2.2) corresponds with Fig. 2.9, Diagram B, which is a sequential composition. This kind of holon composition also corresponds to temporal sequences or processes in physical nature. One way to interpret the diagram is that when a given state is produced from interactions or observations it is part of the contextual topology as well. In a classical context, the effect is to produce the next temporal event in a law-like manner. In a complex context there could be uncertainty and even nonlinear effects. The sequence appears to us as a state change, but in this framework it is a discrete change, like a movie frame. The systemic implications seem to correspond with quantum theory in the sense that events do not really *move* between observations, but are essentially recreated from the context in the newly observed location. If this becomes our accepted view of reality, it is clear that contextual causes cannot be eliminated except in approximations.

The spiral diagram can remain open, or it can at some point close back onto the original condition. For example, a planning series might eventually come back to old models, or in natural science, a spacecraft that travels far enough might return to its origin due to the curvature of space–time. Sequential maps more commonly take a snapshot out of a larger process; a quite legitimate analytical thing to do if the sequence represents a phenomenon of interest; but in that case it is a fractional view. Most of modern science stays within the fractional view.

Figure 2.9, Diagram C represents the case of a second order system closure. This is one of the most interesting cases because it is an explicit representation of complexity. That is, if we assume that the two contexts are not reducible to each other, then the system is uncertain between two rule sets (natural models). Closure means that the two systems are co-dependent (establishing each other) in some aspect. In this case, we show "efficient closure," meaning the two systems share dynamics as, for example, in wave–particle duality or two people building a house with different ideas and plans. Such cases are complex. Closures in the other quadrants can be quite interesting as well. For example, final closure would be a case, in which two people with entirely different plans and behaviors nevertheless share each other's vision. Material closure might describe the situation in mutualism where an animal provides nutrients for a plant that provides food for the animal, or we can find examples in domestic work relations. Formal closure is sharing a plan or boundary conditions.

It is interesting to note that such closures each require an additional holon. If two holons are closed in two ways, the original systems lose their identity and they separate into two reconfigured systems. Two holons with three closures remain closed, but the two systems are redefined and it is then the same as being closed in one quadrant. To retain system identity with more closure requires more holons. So, two closures require three holons and closure in all four quadrants requires five holons, as shown in Fig. 2.9, Diagram D. The fifth order holon is also a very interesting case because that is a complete closure at one level (i.e., not considering the unbounded possibility for sub-components). This causal organization corresponds with Rosen's "M-R System" diagram, by which he showed the minimum internal efficient closure required for a living organism or cell (R. Rosen, 1985, 1991). Note that Rosen's M-R diagram 10C.6 in the 1991 book, *Life Itself,* was misprinted, but later corrections were published in, for example, Cottam, Ranson, and Vounckx (2007), Louie (2009), and Mikulecky (2000), with various commentaries. As such, it represents the causal organization of a whole system, and if we assume it has M-R functions, it thus identifies life. It is arguably a good model for explaining diversity of causal types of life, healthy institutions and corporations, and system sustainability for which measures of health, integrity, resilience, and other systemic properties of a whole can possibly be developed.

Concluding Remarks

Readers may find the blank worksheets (see Section "Appendix: Worksheets") useful for thinking about a relational analysis. A first step in any analysis would be to list the four causal aspects of the system of interest, and to consider if these are about system behavior or system existence. They can be written as separate cycles with various forms of closure. For any given system, one may fill in related cycles (using the worksheets) following any of the configurations in Fig. 2.9, indicating with arrows where closures exist. Each holon framework diagram has eight elements, four of which are described as causes, two that define the system in terms of its ontological categories, and two that define it in terms of its epistemological codings. Thus each category comprises two adjacent quadrants. The categories are paired in the system's ontology (contextual potential and actual phenomena) and its epistemology (decoded functions and encoded exemplars). The origin of the system is thus implicit in its identity categories, whereas the causal quadrants are used to describe how it works or, more explicitly, analyze the causes of its existence. These other forms of analysis will be discussed in Chapter 4.

In applying the framework one quickly discovers that it is often not clear which aspect of a system or study belongs in which quadrant or if some aspect under consideration should be represented as one of the nodes. What will happen is that, as each quadrant or node label is decided, it will become clearer what the others should be to form a single loop relation—a system that can be identified through the study. The process is actually helping discovery of the true identity of the imagined system, which may have been only vaguely known at the outset, somewhat like the game of "Twenty Questions" (although this one has eight). Further, as different sub-systems are defined and the relations between them are worked out, each related system becomes better defined by those relations. Eventually, a picture emerges that is self-consistent and describes the system of interest. A great deal can be learned in this process of definition, such as missing elements, redundancies (that may be stabilizing overall), leverage points, root and hidden causes, attractor patterns, alternative system configurations, and so forth.

The archetypal quality of the quadrants is invariant, which is why it can be applied generally. The invariant nature of the causes is preserved in their cyclical relations to one another. By following the rules of entailment discussed here and in Chapter 4, these diagrams can be very diagnostic. What makes this framework most valuable is its mathematical foundation. Being holistic and infinitely holarchical, the framework can help analyze systems in terms of whole system components and it can also be used in fractional modes of analysis including reduction to classical mechanisms or unactualized subjectivities.

A very simple exercise to become familiar with this approach is to take a typical concept map of a system, in which the arrows and boxes rarely conform to any rigorous types, and simply apply the four causal labels to the arrows and the four category labels to the boxes. Reorganizing into quasi-holons will reveal missing pieces of each implicit identity or redundant or ambiguous components. The idea is to converge on a unique system identity leaving other possibly important aspects of the study in other holons that will later be linked in more appropriate ways. The result is to impose a natural order on the researcher's view and analysis of the subject system.

In order to create a new model, the following questions can be used as prompts:

Questions for labeling the four quadrants (the causalities in the holon diagram and worksheet):

- What is the observable/measureable result or condition of the system being described? (material aspect)
- What actions, agents, or dynamics produce that observable result? (efficient aspect)
- What guides, shapes, or regulates the dynamics? (formal aspect)
- What prior idea, meaning, or exemplar does the guidance follow from? (final aspect)

Here are some questions for labeling the four parts of the system identity (the ontological axis connecting context and action, and the epistemological axis connecting function and structure).

- What *actual system* (system that acts in the world) is indicated by questions 1 & 2 above?
- What *functions* (performances) are implied by questions 2 & 3?
- What *contextual system* (systemic model) is indicated by questions 3 & 4?
- What *structures* (measurable and meaningful patterns) are represented by questions 1 & 4?

The real strength of going to a relational analysis is to discover underlying causes of complexity and patterns of organization. Those patterns, in turn, can then be quantified as to their relative presence or strengths, perhaps by inserting specific models of each type from new or previous empirical research. Where complexity is not significant as compared with predictable behavior, a mechanistic model may do. Where one does not need much specificity about contextual causes, a probabilistic model may do. For more detailed analysis, each quadrant may be further decomposed into sub-holons (or related to describe more inclusive systems).

Each quadrant can thus be the container for an appropriate method written in any terms that work sufficiently for the purpose. The caveat, of course, is not to forget that a potentially limiting or explosive assumption may have been made by doing that. But still the relational framework will help keep track of those instances. Increasingly, complex problems require relational analysis to find causes at greater and greater intricacy depth and increasing possibilities for answers.

The holographic organization means we have the tools to analyze whole systems in terms of whole systems. It also allows us to plug in any useful description into a relational analysis if we make the assumption that deeper analysis is not needed. For this reason, the approach is completely compatible with current analytical methods—it simply adds natural organization to reveal constraints and opportunities. This may seem to contradict the claim that the relational analysis is a fundamental reality, but the point is that using other models formalized heuristically is essentially an approximation to that quadrant's role. The key is not to apply a model that crosses the boundary between contextual and actual system domains—that must be done by coupling models to avoid reduction. Chapter 4 explains details of models as entailment relations, which exist in both contextual and actual system domains.

As a final example, Fig. 2.10 applies the framework to describe the organization of the chapters in this book.

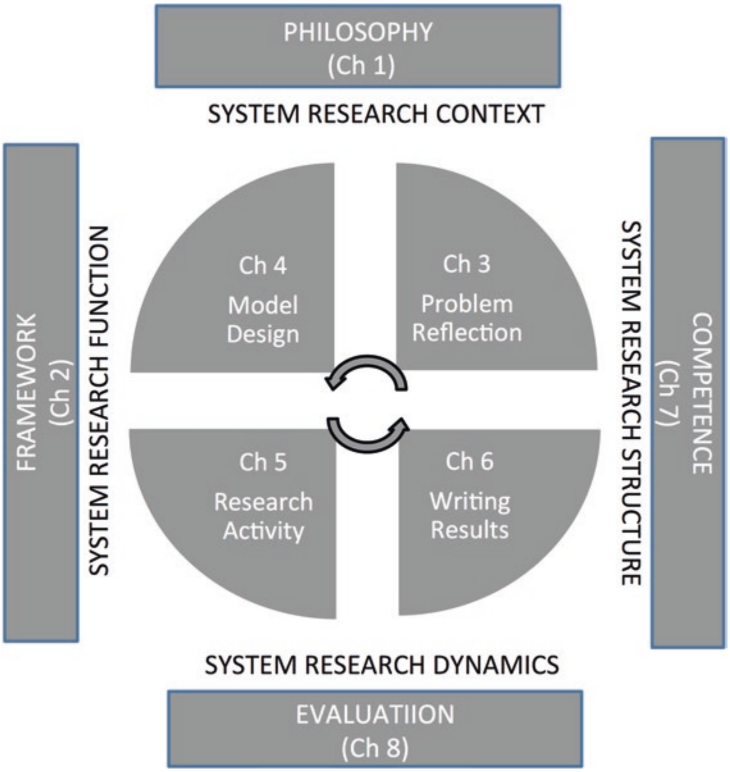


Fig. 2.10 PAR Holon organization of the book chapters

In Chapter 3, Problem Structuring and Research Design, the implications of the framework chosen for systems research are realized. The framework serves as the basis for further analysis of the system, its properties, behaviors, and pathologies. Using a disciplined approach will help clarify the dynamics of the subject system, so a comprehensive description and robust model (Chapter 4) can be developed. Once researchers have a clear understanding of a subject system and the problem to be addressed, even if that "problem" is a theoretical development, Chapter 3 addresses research design to guide researchers in making choices suitable to the system as envisioned.

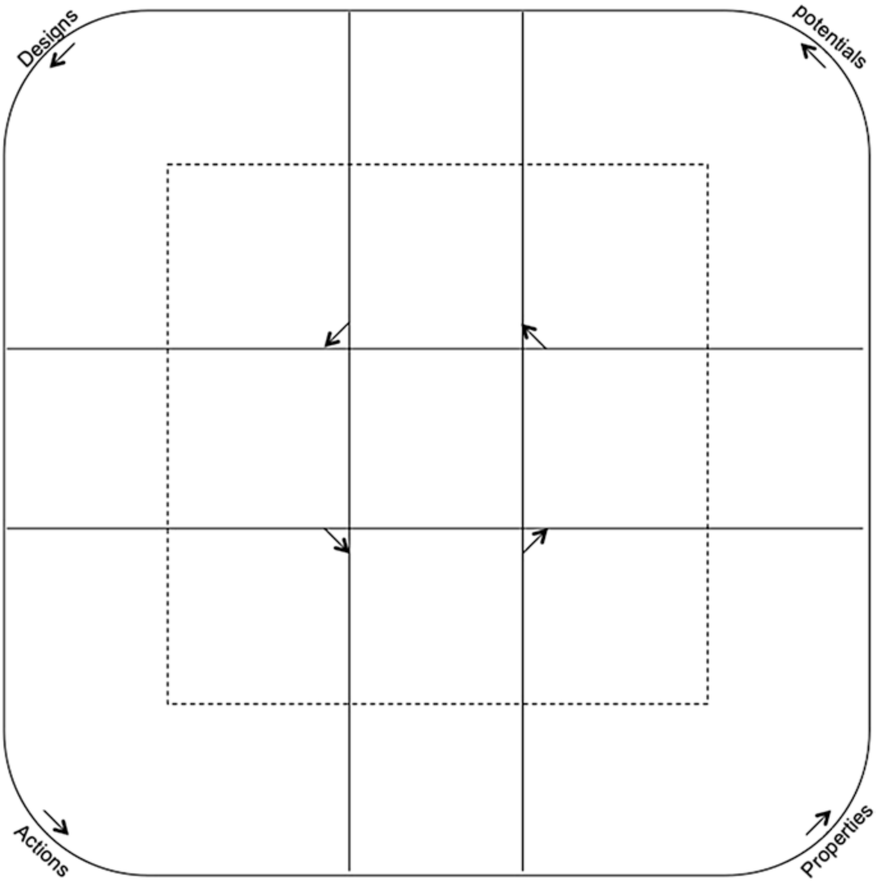
Appendix: Worksheets

1st/2nd Order (open) Holon Worksheet

Combined System: ______________________________

Internal System: ____________________ Notes:

External System: ____________________

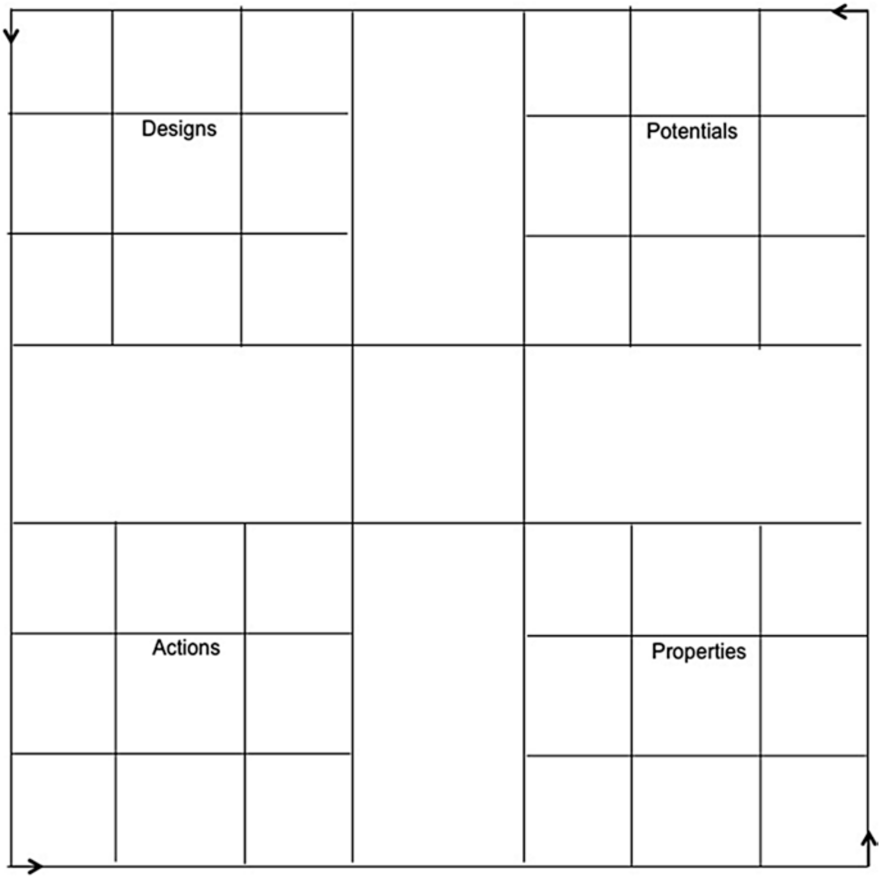


5th Order (closed) Holon Worksheet

This Holon: ____

Parent Holon: ______________________ Notes:

Quadrant Link: ______________________



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Chapter 3
Problem Structuring and Research Design in Systemic Inquiry

Mary C. Edson and Louis Klein

Abstract The central question of this chapter is, "How are inquiries into problems structured and designed to conduct research in a systemic (holistic, comprehensive, complicated, and complex), as well as systematic (logical, rigorous, and disciplined) way?" The focus is on Problem Structuring and Research Design related to the purpose of research and development of an inquiry's central research question(s). Both are predicated on researchers' grounding in systems philosophy and theoretical or conceptual frameworks gained through knowledge acquired through review of the literature, experience, experimentation, or pilot study. These foundations prepare systems researchers for analyzing systems and defining problems to design, conduct, report, and evaluate systemic research studies. In addition, these fundamentals guide researchers' journeys through iterative, nested, and cumulative cycles of learning about subject systems. Researchers will learn about defining systemic research questions and gain understanding about the role and embedment of context, including a system's environment, its stakeholders, and emergent properties. Researchers will gain appreciation and competencies of systemic research that is also systematic by applying principles of adaptive project management. While Problem Structuring is about doing the right research, Research Design is about doing research right using a systemic lens. For systems researchers from disciplines such as the social, natural, and physical sciences, and fields like engineering, economics, and public policy, this question poses exacting challenges in evaluation of credibility, validity, and ethics of Systems Research including application of findings. It poses a dual standard of rigor in requiring that research meet both systematic and systemic definitions and distinctions.

Keywords Systemic • Systematic • Systems analysis • Cycles of learning • Stakeholders • Emergent properties • Adaptive project management • Credibility • Validity • Ethics

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M.C. Edson et al. (eds.), *A Guide to Systems Research*, Translational Systems Sciences 10, DOI 10.1007/978-981-10-0263-2_3

> Don’t get involved in partial problems, but always take flight to where there is a free view over the whole single great problem, even if this view is still not a clear one.
>
> (Wittgenstein, 1984, p. 23e)

Introduction

The previous two chapters of this guide have introduced you to Systems Philosophy and the role of Frameworks in developing a foundation for Systems Research. In this chapter, the focus is on Problem Structuring and Research Design related to the purpose of your research and developing your inquiry’s central research question. The central question of this chapter is, “How are inquiries into problems structured and designed to conduct research in a systemic (holistic, comprehensive investigation), as well as systematic way (logical process and procedure)?” For systems researchers, as well as others from disciplines such as the social, natural, and physical sciences in addition to engineering, this question poses a rigorous challenge in the design and eventual evaluation of the credibility and validity of their work (Sheng, Elzas, Ören, & Cronhjort, 1993). It poses a dual standard of rigor in requiring that research meet definitions and distinctions both systematic and systemic (Carr, 1996; Ison, 2008).

Problem Structuring and Research Design are critical processes in the course of establishing the philosophical foundation, determining the appropriate framework, and developing the model used in your research. They serve as a bridge between the foundation for your research and the actions you take in conducting the study. These two processes relate to the potential and possibility of inquiry into systems through understanding its context, function, and structure to develop research questions through ontology and epistemology. These critical steps in the research process set the stage for action—conducting your research, analyzing the data you collect, and reporting results, which will be discussed in later chapters of this guide.

Is It a System?

Systems research requires deep understanding of a subject system or system-of-systems. In general, systems researchers identify subject systems with intentions of understanding how they organize and operate within their environments when both are changing. It is important to make the distinction between describing versus defining a system. Describing a system conveys attributes, characteristics, and dynamics of your subject to your audience as opposed to “defining a system,” which is a generally accepted definition of what a system is. What a system is largely depends on its context. Describing your subject system is not synonymous with *defining a system* in the context of systems engineering, which details system specifications for the purposes of analysis, design, and development. In the context of systems research, describing your subject system entails explicitly explaining the context and interrelationships in which the system operates and the relevant boundaries you will examine within the scope of your research. As a systems researcher, you will likely use the definition of a system according to your discipline or based upon your thorough literature review of the systems sciences. This definition is a standard or benchmark for the purposes of your research and it is part of choosing your framework. Further, systems researchers will describe a particular system or details of the subject. This distinction is specific and contextual versus general. In addition, it is important to discern a "system definition," as it is used in systems engineering for specification of systems. In most cases, systems researchers are describing subject systems, not defining them unless developing philosophy and/or theoretical foundations.

When describing a subject system, you may find it useful to ask these questions:

- What definition of a system are you using to assess your subject?
- Does the subject have agency (consciousness is a characteristic of human systems, not necessarily other natural or physical systems)?
- How is it organized?
- How does it communicate internally and externally?
- How does it operate and regulate itself internally?
- How does it operate, adapt, and influence externally?
- What are its boundaries and thresholds for survival?
- How flexible or permeable are those boundaries?
- What are its interdependencies and relationships with its environment?
- What are the consequences of its existence and its extinction on the viability of the larger system (i.e., requisite variety, interdependence, holism)?
- What are the strategies that support and advance or dissolve and dissipate the system?

Seeing (understanding) systems means more than recognizing patterns by delving into the relationship between the levels of an entity's organization and operation within its environment to determine the scale, scope, and impact of its behavior in and on the system as a whole. Thus, investigating systems will entail examination of the subject's potentials for self-organization (Ashby, 1947), cybernetics (Ashby, 1956), hierarchy (Ahl & Allen, 1996), autopoiesis (Maturana & Varela, 1980), feedback (Sterman, 1989, 2000, 2002), adaptation (Holland, 1992; Gunderson & Holling, 2002), emergence (Goldstein, 1999; Hofstadter, 1979; Lewes, 1875; Steels, 1990), and learning (Argyris & Schön, 1992). Ultimately, an underlying question is, "Can the whole be expressed as a sum of its parts?" If not, then the subject may be a system. As a systems researcher, your role as primary investigator is to explicitly explain the essence of the system. The challenge for most systems researchers is developing an explicit description with parsimony (Popper, 1992; Wittgenstein, 1922; see Chapter 2).

A Systemic Perspective

In essence, a systemic perspective enriches your research on two levels by addressing an inner logic and an outer logic (see Table 3.1). Using inner (internal, subject specific) logic, a systems perspective contributes theories, methodologies, methods and tools. Using outer (external, systems environment) logic, a systemic perspective relates your subject system to its relevant context and its stakeholders. This perspective may be described as a project management aspect of research. Applying a systemic perspective to research in terms of project management may be novel to research. Based on experience, project management can be beneficial for the research as well as for the researcher.

Table 3.1 Systems perspective integrating inner and outer logic

Doing/logic	Doing the *right* research (Problem structuring)	Doing the research *right* (Research design)
Inner logic (research system)		
Outer logic (stakeholder and environment)		

Problem structuring and designing your research is a learning cycle. Each of the four perspectives in the above table will inform the other three. It will concomitantly limit and provide new possibilities. Using these perspectives to shape your inquiry prepares you for decisions which will further shape your research and determine the course of action. The better you structure your problem and design your research, the more likely your research will yield useful and relevant outcomes.

Much of Problem Structuring and Research Design entails questions you will be asked as the primary investigator by your audience, including the Institutional Review Board (IRB), your dissertation/thesis committee, your funders, your constituents, your colleagues, and those either reading and/or applying your findings, such as decision and policy makers in governance. Having a clear sense of how you will address these questions will provide a solid foundation for conducting, analyzing, reporting, and evaluating your research.

Suggestion

- During the course of developing your research study, you will make many choices and decisions that will have consequences on the direction and outcome of your research. It is wise to keep a journal chronicling the rationale you used for making choices and decisions. Keeping a journal of your decisions will help you reflect upon them during your analysis of the data. You will also find it a source of possible recommendations for future research.
- Debriefing after a research study is completed enhances your learning, as you develop future research strategies based upon what happened, what did not, and what could have been done differently.

Problem Structuring

Problem structuring entails explicit articulation of details of the rationale for your inquiry and its design with your audience. As John Dewey (1938) said, "A problem well put is half-solved" (p. 108).

According to Woolley and Pidd (1981), problem structuring is "the process by which the initially presented set of conditions is translated into a set of problems, issues, and questions sufficiently well-defined to allow specific research action" (p. 197). While Wooley and Pidd's target audience was practitioners in Operations Research (OR), their problem structuring rationale applies to systems research because of its focus on complex, real world or *wicked problems* (Churchman, 1967; Rittel & Webber, 1973, p. 160), and the essence of such fundamental questions as:

- What is the real problem?
- How do you know you are working on the right problem?
- How do you decide what to do about the problem?
- How do you set limits to the area of investigation in a project? (Woolley & Pidd, 1981, p. 197)

Answering these four fundamental questions will help you determine your central research question and subsequent questions, the relevance of your research and its audience, the scope of the subject system and the scope of your research, as well as methodologies for research design and data collection with a high potential to lead to deeper understanding of the problem and strategies for addressing it.

Suggestion

- Be explicit and crystal clear in communicating your primary and secondary research questions. Keep them straightforward and uncomplicated. Even the best articulated questions can quickly become complex as your research study unfolds. The KISS (Keep It Simple and Straightforward) principle will help you stay out of rabbit holes and digressions from the primary purpose of your research. This may take some intellectual distillation on your part, so you hone your inquiry to its essence. It may be useful to test your questions by asking for guidance from others whom you trust. A pilot study can help you refine your research questions.

In planning research that is systemic, as well as systematic, you will want to answer several questions early on in the development of your inquiry. These include:

- What is the purpose of your inquiry? Why is it important and for whom does it matter?
- What compels your inquiry? What is driving you to find answers? What is your motivation?

- Why are you asking these questions now?
- Who is your target audience for reporting the results of your inquiry and why will they be interested in its outcomes. This is the "So what?" question to which your audience and committee will want clear answers from you.
- What is the basis or foundation for your inquiry?
- What is known about the subject? What is yet to be known?
- What is the current situation? What is the gap? Will your research propose a way to bridge this gap or is that not yet anticipated?
- How are you describing the subject system, its context, its boundaries, its space–time–meaning dimensions?
- Does the subject system include human actors? If so, how will they be involved in the study and how will they be protected? Explain the ethical implications of your research.
- What other actors are in the subject system and how will they be protected or ethically addressed?
- Do you have anticipated outcomes? If so, what consequences of your research do you also anticipate?

In the early stages of developing your research ideas, you might find tools such as radial (e.g., mind or concept) mapping (Davies, 2011) or design thinking tools (Brown, 2008) useful in conceptualizing and/or visualizing your research. By seeing your ideas in a relational way, you gain insight into interconnections you may overlook using linear approaches. You will discover concepts that need exploration and development, which will help you choose your strategies for problem structuring and research design.

Figure 3.1 is an example of the use of mind mapping to capture and organize your thoughts about your research as early steps in the problem structuring and research design phases. This figure shows an early mindmap of the conceptualization of this book. As you develop your ideas further, you may want to consider other cognitive approaches such as DSRP (distinctions, systems, relationships, and perspectives; Cabrera, Cabrera, & Powers, 2015).

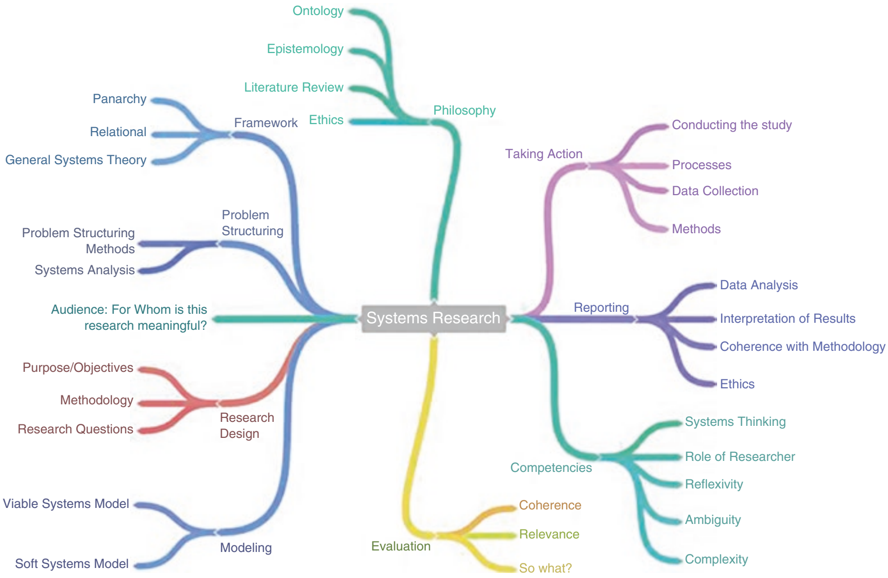

Fig. 3.1 Mind mapping of problem structuring for research design

Problem structuring can help you develop your responses to these questions. Rosenhead (1996) began by asking, "What is the problem" (p. 118)? To understand how problem structuring can help you answer this question for your inquiry, history will provide some understanding.

The legacy of problem structuring stems from OR and Management Science (MS) since the late 1960s. Initially, methods used for problem structuring emphasized objectivity; however, systems thinkers like Churchman (1967), Ackoff (1979), and Checkland (1983), were critical of this approach because it constrained application to well-defined problems. As systems thinkers, all three recognized its flaws as the complexity of real world problems advanced. In particular, Ackoff (1981) recognized most real world problems as "messes." As Rosenhead (1996) stated, "Problem structuring methods provide a more radical response to the poor fit of traditional OR approaches for wicked problems—a response based on the characteristics of swamp conditions rather than on the preexisting investment in high-tech solution methods" (p. 119).

Problem structuring methods (PSM) are better suited for situations that are characterized by unstructured hierarchies, sophisticated actors, nonlinearity, unpredictability, and changing priorities. As such, problem structuring lends itself to modeling complexity graphically rather than algebraically or quantitatively (White, 2006). Mingers and Rosenhead (2001, 2004) summarized the application of problem structuring as being well suited to unstructured problems characterized by:

- Multiple perspectives,
- Incommensurable and/or conflicting interests,
- Important intangibles, and
- Key uncertainties (Mingers & Rosenhead, 2004, p. 531).

Problem structuring is a way of modeling a situation (a model or multiple models), so participants can "clarify their predicament, converge on a potentially actionable mutual problem or issue within it, and agree [on] commitments that will at least partially resolve it" (Mingers & Rosenhead, 2004, p. 531). Mingers and Rosenhead (2004) advise that the application of problem structuring should:

- Enable several alternative perspectives to be brought into conjunction with each other;
- Be cognitively accessible to actors with a range of backgrounds and without specialist training, so that the developing representation can inform a participative process of problem structuring;
- Operate iteratively, so that the problem representation adjusts to reflect the state and stage of discussion among the actors, as well as vice versa;
- Permit partial or local improvements to be identified and committed to, rather than requiring a global solution, which would imply a merging of the various interests (Mingers & Rosenhead, 2004, p. 531).

The following is a summary of several PSM, from Rosenhead (1996) and Mingers and Rosenhead (2004) (Table 3.2).

Table 3.2 Summary of problem structuring models

Model type	Description
Decision conferencing	"is a variant of decision analysis. Through collaboration, it builds models to support choices between decision alternatives, especially in cases with multidimensional consequence when there is uncertainty about future events likely to impact outcomes. In a facilitated workshop, a group develops a model including probabilities and utilities with a goal of shared understanding, purpose, and commitment to action (Phillips, 1989, 1991; Watson & Buede, 1987)." (Mingers & Rosenhead, 2004, pp. 532–533)
Hypergame analysis	"is an interactive approach to taking action in conflict situations. It emphasizes (a) exploring the pattern and nature of interactions between the actors, and (b) the effect of differences of perception among the actors about what actions are possible, about preferences between outcomes, and so forth (Bennett & Cropper, 1986)." (Rosenhead, 1996, p. 121)
Interactive planning (also called idealized planning)	"is a method with the ambitious aim of designing a desirable organizational future and ways of bringing it about. Analysts generate a reference scenario to demonstrate the dire consequences of not taking action. This motivates a participative process in which participants create an ideal design for the future of their organization. Otherstages of the method deal with how to bring this future into existence (Ackoff, 1979, 1981)." (Rosenhead, 1996, p. 121)
Metagame analysis	"is an interactive method of analyzing cooperation and conflict among multiple actors. Analysts using supporting software work with one of the parties. They elicit from them decision options for the various actors, from which they construct possible future scenarios. Analysts and actors use these as a framework to explore their ability to stabilize the outcome at a more preferred scenario, by the use of threats and promises (Howard, 1993)." (Rosenhead, 1996, p. 121)

(continued)

Table 3.2 (continued)

Model type	Description
Process theory	"is an approach to science, perception, and measurement developed by Rosen (1978, 1991) using a modeling relation of encoding and decoding. It is applied in anticipatory and complex systems (Mikulecky, 2010)." (Rosenhead, 1996, p. 121) The modeling relation is explained in Chapters 2 and 4.
Robustness analysis	"is an approach that focuses on maintaining useful flexibility under uncertainty. In an interactive process, participants and analysts assess the compatibility of alternative initial commitments with possible future configurations of the system being planned for, and the performance of each configuration in feasible future environments. This enables them to compare the flexibility maintained by alternative initial commitments (Rosenhead, 1980)." (Rosenhead, 1996, p. 121)
Soft systems methodology (SSM)	"is a general method for system redesign. Participants build ideal-type conceptual models, one for each relevant world view. They compare them with perceptions of the existing system in order to generate debate about what changes are culturally feasible and systemically desirable (Checkland, 1981; Checkland & Scholes, 1990)." (Rosenhead, 1996, p. 121)
Strategic assumption surfacing and testing	"is a method for tackling ill-structured problems where differences of opinion about what strategy to pursue are preventing decision. Participants are divided into groups, each of which produces a preferred strategy and identifies the key assumptions on which it is based. The reunited groups debate these strategies and assumptions, mutually adjusting their assumptions on the way to an agreed solution (Mason & Mitroff, 1981)." (Rosenhead, 1996, p. 121)
Strategic choice approach (SCA)	"is a planning approach centered on managing uncertainty in strategic situations. Facilitators assist participants to model the interconnectedness of decision areas. Interactive comparison of alternative decision schemes helps them to bring key uncertainties to the surface. On this basis, the group identifies priority areas for partial commitment and designs explorations and contingency plans (Friend & Hickling, 1987)." (Rosenhead, 1996, p. 121)
Strategic options development and analysis (SODA)	"is a general problem identification method that uses cognitive mapping as a modeling device for eliciting and recording individuals' views of a problem situation. The merged cognitive maps provide the framework for workshop discussions, and a facilitator guides the group towards commitment to a portfolio of actions (Eden, Jones, & Sims, 1983)." (Rosenhead, 1996, p. 121)
Systems dynamics (SD)	"is a way of modelling people's perceptions of real-world systems based on causal relationships and feedback. It was developed as a traditional simulation tool but can be used, especially in combination with influence diagrams (causal–loop diagrams), as a way of facilitating group discussion (Forrester, 1994; Lane, 2000; Vennix, 1996)." (Mingers & Rosenhead, 2004, pp. 532–533)
Viable systems model (VSM)	"is a generic model of a viable organization based on cybernetic principles. It specifies five notional systems that should exist within an organization in some form—operations, co-ordination, control, intelligence, and policy, together with the appropriate control and communicational relationships. Although it was developed with a prescriptive intent, it can also be used as part of a debate about problems of organizational design and redesign (Beer, 1984; Harnden, 1990)."(Mingers & Rosenhead, 2004, pp. 532–533)

Beyond traditional PSM, there are other methods for analyzing problems: critical systems heuristics (CSH; Ulrich, 2000), SWOT analysis (Weihrich, 1998), scenario planning (Schoemaker, 1998), the socio-technical systems approach (Cytrynbaum, Trist, & Murray, 1995; Emery & Trist, 1965; Trist & Murray, 1993), "organizational culture assessment" (Schein, 2004, pp. 337–348), and resilience assessment (Gunderson et al., 2010).

In addition, multimethodology uses multiple problem solving and research methods (pluralistic) to leverage strengths while mitigating weaknesses of individual, often isolated methods for robust analysis (Mingers & Brocklesby, 1997; Munro & Mingers, 2002).

Clearly understanding and explicitly describing the system you will be studying is a critical process in problem structuring and determining the relevance of your research. In considering the subject system, your analytical stance will determine the extent of *systemicity*, the complex and dynamic behavior of systems and systems-of-systems, or "Weltanschauung" (comprehensive worldview), you will address in the analysis of your findings (Checkland, 2000). The scientific method isolates phenomena, relies on objective observation, and tests hypotheses. The scientific method views phenomena in controlled environments, which are considered *closed* systems (see Chapter 8 Evaluation). Boundaries are rigidly defined and fixed. The goal is to understand the individual phenomenon alone, not holistically. One of the most compelling reasons for adopting a systemic approach to inquiry is the complex nature of phenomena in the context of their environments. If complexity is driving your inquiry, then your perspective will be viewing the subject system as *open*, which accounts for phenomena operating in context of the natural environment with flexible or permeable boundaries (Ackoff, 1971; Forrester, 1994; Ulrich, 1995).

In analyzing problems in open systems, description of the subject system must account for the dynamics and interrelationships between relevant stakeholders. In addition, the description must explicitly describe the dynamics of environmental change and its impact on the phenomena.

Role of the Systems Researcher in Problem Structuring and Research Design

Consider your role as systems researcher and explicitly communicate it with your audience. This includes understanding your motivations and intentions in conducting your research (Conneeley, 2002; Munkejord, 2009).

Questions you will want to ask yourself include:

- What is my position or stance relative to the system to be studied?
- Am I *in* the system, but not *of* the system? Or, am I an agent of change *relative* to the system?

- Will my role be any of the following:
  - *Observatory*
  - *Participatory*
  - *Interventionist*
- What is the extent or degree of agency I will have in the system?
- How will I account for my presence, influence, and impact in/on the system?
- What are the risks of being *in* or *of* the system? Am I at risk for "going native?"
- What is the extent of benevolent bias (i.e., intention to influence the system for improvement; Elliott, 1977)?

Examples: Retrospective Case Study (Yin, 2013), Grounded Theory (Charmaz, 2014), Repertory Grid (Fransella, Bell, & Bannister, 2004; Jankowicz, 2003) as opposed to Action Research (Reason & Bradbury, 2001; Stringer, 2013) and PAR (McIntyre, 2007; Whyte, 1991).

Rationale for Systems Research

Developing well-reasoned arguments (Weston, 2009; Weston & Morrow, 2015) is an essential process for communicating the rationale for your inquiry. Through this process you will be using different types of reasoning to create a foundation for your research that is systematic, systemic, and sound. A suitable rationale for your research may suggest specific methodological and scientific frameworks. Be mindful of your decisions. Specific frames of reference suggest specific rationalities. While frameworks offer useful structure and support the communication of meaning, once you have chosen to work within a specific framework you also tend to be constrained. It is important to explicitly recognize and acknowledge the limitations and delimitations of the framework you choose.

As a Systems Researcher, it is important to understand and apply different types of reasoning, as well as distinctions about causality and the use of analogies and metaphors. In the process of conceptualizing your research, it will be useful to you to understand different types of reasoning and inference, so you can choose research approaches, apply research methodologies, develop research methods, or combine them, as in mixed methods research. As humans, we are sense- and meaning-makers (Weick, 1995). Our drive to understand our environment, our interrelationships with it, and one another, is at the heart of research. Therefore, it will be important to understand the relationship between inference and causality. Here are some distinctions:

Abduction (abductive reasoning or inference) is a form of logical inference in which a theory is based upon observation and finding the most uncomplicated and likely explanation. Examples of application of abductive inference are artificial intelligence, computer science, and expert systems. Philosopher and pragmatist, Charles Sanders Peirce (1839–1914) was an early proponent of abduction in which an explanation from an observation is made as a matter of course. In vernacular, this is referred to as an "obvious conclusion." Abduction does not guarantee a correct conclusion based upon its premises. For example, an observation of wet dog paws after a dog comes indoors from outside in the morning may indicate that it had rained. It may also indicate morning dew, sprinklers had irrigated the lawn where the dog walked, the dog had stepped in its outdoor water bowl, or that someone had cleaned its paws. Abduction is frequently combined with other forms of reasoning, such that Carson (2009) remarked that Sherlock Holmes did not rely solely on deduction but in concert with abduction and induction.

Deduction (deductive reasoning or inference) is a form of logical inference in which premises are directly linked to a certain conclusion. Examples of deduction, which is also referred to as reductionism, is most scientific research, geometry, and mathematical proof (as opposed to mathematical induction). Aristotle (384–322 BCE) is generally recognized as the developer of this logic. Deduction conforms to one or the other of three laws:

1. Detachment—a single conditional statement is combined with a hypothesis to deduce a conclusion, or
2. Syllogism—two conditional statements form a conclusion, or
3. Contrapositive—a conclusion is proven false, then the hypothesis is also false.

Historically, deduction uses a closed system assumption (i.e., what is known is true, what is not known is not true) as opposed to an open system assumption (i.e., lack of knowledge does not presume falsity; Reiter, 1978). Other examples of deduction are causal conditional or "if-then" and "if-then-else" statements. Applications of deductive inference include criminal investigations using biological evidence such as DNA. Both scientific research and forensic science rely on validity and reliability of their arguments.

Induction (inductive reasoning or inference) is a form of inference in which a theory emerges from observing patterns and then looking for evidence. It is often defined as reasoning that develops general principles from specific observations. It is particularly useful in the early stages of new theory development when little is known about a phenomenon.

Suggestion

- While Sherlock Holmes was considered a master of deductive reasoning, he relied on induction and abduction too. As a Systems Researcher, Holmes's application of these three types of reasoning was grounded in good judgment; however, his data collection techniques were often caustic, especially when human actors were involved. Avoid adopting Holmes' high functioning sociopathic approach when working with human actors because it will limit the richness of the information and data you collect. During problem structuring, you may interview stakeholders who understand the intricacies of the system you want to study. Using your social emotional intelligence (Goleman, 2006) will help you develop an accurate description based upon the information you are able to gather. For more about competencies of systems researchers, see Chapter 7.

Causation is the relationship between cause and effect. Causality is an inference that an effect has a direct or indirect cause. David Hume (1711–1776) and John Stuart Mill (1806–1873), two philosophers, made distinctions about causation. Hume brought attention to the errors in causal beliefs, noting that conditional statements can obscure true causation and, therefore, are insufficient. Hume noted that we have limitations in our capacity of observation and may overlook other attributes. Mill devised five criteria for confirmation of causality: (a) agreement, (b) difference, (c) joint agreement and difference, (d) concomitant variation, and (e) residues. Reliability of these criteria rests on relevance to the subject system under observation. These criteria of induction may be best applied to confirm observation of patterns for development of theories that may generate hypotheses. Inductive reasoning is a foundation used in Grounded Theory (Glaser & Strauss, 1967) and other qualitative research methods (Creswell, 2012, 2013; Creswell & Clark, 2007).

Suggestion

- One of the competencies (see Chapter 7) of adept systems thinkers is the capacity to hold two or more seemingly disparate ideas and reconciling them. This is the case with emergence, problem structuring, and research design. Anticipate emergence, trust the process, be prepared to articulate the unanticipated and unintentional consequences of your research for yourself and your subject system (reflexivity). Think about incorporating feedback for learning.

Creating Shared Meaning: Metaphors, Similes, Analogies, Allegories, and Isomorphisms

In the processes of problem structuring and developing your research design, your interactions with stakeholders in the subject system will be critical in developing an accurate understanding and description of the systemic issues of your inquiry. Much of this interaction is dependent on your ability to create meaning and shared understanding with stakeholders. In addition to frameworks and models, systems researchers often rely on metaphors, similes, analogies, and allegories to communicate complex ideas in comparative ways so their stakeholders and audiences can relate conceptually. Systems researchers also use isomorphisms to illustrate relationships between concepts or models.

A *metaphor* is a comparative figure of speech to relate two ideas using one to mean another. For example, “S/he is burning the candle at both ends,” infers exhaustion. When someone says, “Soon I will feel right as rain,” it is not taken literally but figuratively. Similes are types of metaphors that compare two things to create new meaning. For example, “S/he sprints like a cheetah,” explicitly compares two different things using “like” or “as.”

An *analogy* is similar to a metaphor, yet more complex, because it infers a logical argument of likeness that extends beyond initial comparison. Analogies compare similarity through shared characteristics, features, structures, or functions. For example, mechanical systems like cars are often used to illustrate similar human body functions for simplicity, such as food is fuel for the body. In outlining rules for arguments, Weston (2009) demonstrated the use of analogy. He argues that human bodies are like cars as follows: Medical professionals often attempt to convince patients of the merits of annual physical exams by suggesting that these exams are like taking a car in for regular service (p. 19). Since people value the functioning of their cars, the argument follows that they will have similar regard for the health of their bodies. *Allegories* extend beyond analogies. They use narratives to infer covert meanings and motivations, sometimes with moral or political undertones.

In general, *isomorphisms* are understood to be correspondences or parallels in form, structure, and/or function. In biology, isomorphisms are similarities of form and structure between organisms. In organizations, isomorphisms are similarities between the processes or structures of one organization with those of another by imitation or independent development under analogous constraints (e.g., context and boundaries).

Suggestion

- Use of mechanical analogies and metaphors fall far short of accurate parallelism with the dynamics of complex systems for most systems researchers. Going beyond two-dimensional media using new ways to communicate systemic properties and dynamics is necessary. Consider exploring technology for modeling and simulation using media like video and 3-D printing that can provide a robust way to share meaning with your target audience.

Three types of institutional isomorphism are: normative, coercive, and mimetic. Byrne (1998) defined isomorphism in the context of complexity theory in the social sciences:

> This term applies at the point where ontology and epistemology meet in practice in any scientific description of the world, although it is most usually applied in relation to quantitative description. A description and the world are isomorphic when the elements of the description correspond to entities in the real world and when the rules describing the relationship among elements in the description correspond to actual relationship among entities in the real world. The quantitative consideration of isomorphism depends on the transformation of uninterpreted into interpreted axiomatic systems. Abstract mathematical systems in which the terms in equations have no meaning outside the mathematical system are "uninterpreted axiomatic systems." When the terms in the equations are considered to describe real entities and the relationships among them, then the system is interpreted and is only valid if the abstract mathematics are isomorphic with reality. Usually this sort of discussion is conducted in relation to measurements at the ratio scale level and the generation of law like rules taking the form of equations, but it is equally applicable to simple typology generation and the representation of reality, not through equations, but the geometrical depiction. (p. 173)

As François (2004) notes, Stafford Beer made the distinction of *cybernetic isomorphism* as a recursive property of viable systems. Keep in mind that in mathematics, isomorphisms (equivalents) are homomorphisms or morphisms that admit an inverse. An automorphism is an equivalent whose target and source coincide. Depending on your subject system and audience, recognize these distinctions and be prepared to address them.

Understanding the use of inference and conceptual models to convey meaning to create shared understanding is part of the process of problem structuring that segues to Research Study Design in Systems Research. As a systems researcher, you will want to use inference and conceptual models judiciously to help your audience understand the nature, scope, and implications of your work. In the next section, Research Study Design is further explained.

Research Study Design

Research design is an explicit plan detailing the activities that you will undertake to obtain data and perform analysis to develop answers to your inquiry, specifically your research question(s). In your research design, you will articulate and illustrate the path you will take to enroll participants, collect data, analyze data, and report your findings. This section focuses on the planning process you use to create and develop your research study design. It will address the question, "What type of research design, including approach and methodology, is best suited systematically and systemically to investigate the subject system based upon the outcomes of your problem structuring analysis?"

Some of the most frequently used research design types depend on the purpose of the research and include:

- Review—literature review, systematic review for knowledge gathering and theory or hypothesis development;
- Descriptive—case studies, narratives, and ethnographies;
- Correlation—controlled case study, observation;
- Semi-experimental—experiments performed in the field;
- Experimental—controlled and double-blind studies used in scientific research;
- Meta-analysis—comprehensive review of studies examining the same research question(s).

Other considerations are context and duration in which phenomena are observed and data are gathered. For subjects sharing a profile of characteristics, a cohort study may be used to examine patterns. In cross-sectional studies, a specific population or representative subset is chosen to identify causal effects. Longitudinal studies rely on repeatability of prior research studies and examine correlations over the long-term. Cross-sequential studies combine cross-sectional and longitudinal designs, thereby reducing the inherent issues with both.

How will the study be conducted? What methodology will be used? What methods will be used? You may consider fixed design, such as experimental using dependent and independent variables with control, or non-experimental including correlational/relational and comparative, or flexible design, for example, case study, ethnography, grounded theory using quantitative, qualitative, or mixed methods.

New systems researchers may find choosing a research methodology to be overwhelming considering the variety of approaches available. As you consider different research approaches, you will want to consider the following:

- Is the inquiry confirmatory? That is, since the interrelationships are known between variables or actors, will a higher level of confidence be achieved with the results of additional study? Will an *a priori* theory or hypothesis be tested? In this type of inquiry, emergent phenomena are neither sought nor accounted for in the data analysis and reporting.
- Is the inquiry exploratory? That is, will potential interrelationships between variables or actors be examined? Will an *a posteriori* theory or hypothesis be generated from the exploration? In this type of inquiry, emergent phenomena are analyzed and accounted for in the data analysis and reporting.

As part of problem structuring, you will have described the subject system and your position or stance relative to it (i.e., observatory, participatory, interventionist) and the extent of your agency (influence) during your research study. In addition to understanding the relationships of the system, your Research Study Design accounts for other information you have gathered through the Literature Review and how you will integrate that information (if at all) in your analysis. In your Research Study Design, you explain your systemic perspective or the lens/lenses you will use to gather and analyze data in the subject system.

In some Systems Research, the literature review provides theoretical basis for research questions. Determination of your theoretical grounding should be not only rigorous, but systemic. You may choose more than one theory because one alone is not sufficient. If you choose to compare and contrast theories, possibly to develop new theory, then you may decide to use theoretical pluralism (Midgley, 2000). Buds of theory development can be observed through qualitative investigation using several approaches including theoretical pluralism. The extent to which you apply the knowledge you gain through your literature review depends on the degree of inductive reasoning you will be using through the research methodology you choose.

For example, if you choose *grounded theory* (Glaser & Strauss, 1967), then its highly inductive approach means your literature review provides essential information about the system itself but will not determine the specifics of your research questions. Inductive research designs are intentionally ambiguous to elicit emergent properties within systems. As a systems researcher, you will not be explicit in your questions (i.e., they will not be closed-ended hypotheses for testing, but open-ended inquiries). You will be explicit in how you intend to address emergent phenomena. In your Research Study Design, you need to clearly answer the following questions:

- How will emergent properties be addressed?
- Once revealed, how will emergent properties be confirmed or disconfirmed?
- How will emergent properties be tracked and reported?

Systemic Research Design inherently involves complexity on multiple levels ranging from your view of the subject system as a systems researcher to integrating emergence on a personal level. Most likely, it is all connected; however, clarity about your role as researcher in conveying the most relevant information about your subject system is your primary responsibility to the system and to your audience.

Suggestion

- Emergence during your research study is likely to occur in the subject system. While you can anticipate that emergent phenomena will occur, it is unlikely you will be able to anticipate exactly how it will appear and what it will look like. As a systems researcher, on the research study level, be astute to take notes of when unanticipated activities and behaviors occur in the subject system and its context. Based on your preference, your notes may be compiled in a journal or more formally tracked using software of your choosing. If you are using qualitative data analysis software (QDAS) such as atlas.ti or NVivo, you may choose to develop codes to track emergent phenomena. Emergent data are valuable when you complete data collection, compile your results, and reflect on your findings. In Systems Research, the emergent data can be as or more informative than the data formally collected in direct relation to the research question(s).

During this phase, you will consider how you will collect and analyze the data through several questions:

- What data are required?
- How will the data be acquired and collected?
- What methods meet the requirements of data collection and analysis of the inquiry systemically and systematically?
- What analytical approach will be used (e.g., critical systems heuristics, Ulrich & Reynolds, 2010, methodological pluralism—mixed methods, Midgley, 2000)
- Will you use multiple levels of analysis or other analytical approaches? If so, which ones?
- How will you document your data collection and analysis process?
- What technologies will you use to help you organize and analyze the data (e.g., SPSS, STATA, SAS, altas.ti, and NVivo)?
- How much will you rely on qualitative or quantitative data analysis software to perform the analysis?
- How close to the data do you expect to be during transcription or other compilation processes?

While you may not know what to expect during the course of your research study, you can be explicit about your processes of data collection and analysis.

Anticipating the unexpected lies not in knowing the details beforehand but knowing what to do with the knowledge you have gained and communicating with your target audience.

Suggestion

- You may find that you are dealing with emergence on multiple levels during your research. As a systems researcher, on a personal level, you may encounter several "surprises" or incidents that you did not expect during the course of your study. It is best to plan for and expect the unexpected and take it in stride knowing that these occurrences are part of your learning process as a researcher. Do what you can to be proactive, giving yourself space to recover from unanticipated events, yet do not fear them. They are often the richest part of your research journey.

Through clear and explicit Problem Structuring and Research Study Design, systems researchers create a foundation for rigorous research that can lead to creative problem solving and systemic intervention (Flood & Jackson, 1991) to address wicked problems.

Summary

To understand wicked problems confronting the contemporary world, systems researchers need the knowledge, skills, abilities, capacities, and competencies to develop keen insight into issues. This expectation demands Problem Structuring and Research Design that go beyond traditional approaches to research and are not only rigorously systematic, but robustly systemic. This need calls for systems researchers who can assess these problems accurately and communicate the implications to audiences clearly. In addition, systems researchers may need additional skills in evaluating subject systems for adaptability and resistance to change (i.e., adaptive capacity), especially in complex adaptive systems interconnected with complex adaptive social systems (Edson, 2012).

Problem Structuring is a critical step in visualizing, articulating, and documenting the major purpose, motivation, and questions driving your inquiry. The clarity in which you conceive of the research questions sets the stage for your Research Design. Essential questions you need to ask are:

- What is the purpose of the inquiry?
- Why is it important?
- Who will use the research findings?
- What is the scope of the research?
- What are the limitations and delimitations of this research?
- What contribution does it make?

- What are the implications of research that is inconclusive?
- How will emergent phenomena be handled?

By comprehensively understanding and describing the system you are studying through Problem Structuring and Research Design, you develop a rigorous approach to conducting Systems Research that is both systematic and systemic. In Chapter 4, Modeling will be introduced. In concert with Problem Structuring and Research Design, Modeling can help you explicitly communicate the complexity of your inquiry with your audience because models help create shared meaning (Weick, 1995) leading to shared, collaborative action, as explained in Chapter 5.

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Chapter 4
Modeling and Simulation

John J. Kineman

Abstract Modeling in academic and applied disciplines has many interpretations, often confusing true modeling with simulation and analogy. In this chapter, we focus on extensions of the work of the mathematical biologist Robert Rosen to examine a formal view of whole system analysis and modeling. Rosen (1993) defined modeling as the "judicious association of a formalism with such external referents" (p. 359). By *judicious* is meant following certain epistemological criteria that ensure good science and help resolve philosophical differences between realist and instrumentalist approaches. While adopting a primarily realist position on modeling (that models describe nature), the modeling framework also represents constructed phenomena (perceptions and agreements about nature). The resolution of these views is found in reifying models themselves in both nature and cognitive processes. Building on the PAR Holon Framework presented in Chapter 2, we describe four kinds of model, each associated with one of the quadrants in the cyclical framework, and a fifth level of meta-modeling associated with the identity cycle of a system (the framework itself). We describe the mathematical basis for relating models in the framework using category theory adapted for this purpose; and we discuss the technical differences between modeling, simulation, and analogy, giving familiar examples and recommending future development. The reader will gain basic tools to apply whole systems analysis and modeling to complex problems.

Keywords Realist • Pragmatist • Cognitive processes • Cycles • Category theory • Modeling • Simulation • Analogy • Whole systems analysis

> "…it is the judicious association of a formalism with such external referents that is the essence of a (mathematical) model."
>
> (R. Rosen, 1993, p. 359)

In structuring a problem and designing research, modeling can provide additional clarity about the problem and research needs, and in forming either hypotheses or scenarios for verification. A model is a formal representation of the issue being investigated, meaning that it expresses the issue and possible outcomes in technical

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M.C. Edson et al. (eds.), *A Guide to Systems Research*, Translational Systems Sciences 10, DOI 10.1007/978-981-10-0263-2_4

terms that can be tested or investigated. Most often it is not so much the model as the modeling process of working with data and testing their possible meanings that is helpful to the systems researcher in reasoning about or managing a system. A variant of modeling is simulation, which has similar aims—yet less rigorous—about the causes of a system's operation or existence, and mainly intended to mimic its behavior. Both have important uses in the systems sciences.

The subject of modeling has varied treatments in the systems sciences (see for example, Forrester, 1987; Maani & Cavana, 2000). Here we do not attempt to review the field, but instead provide a bridge into the world of modeling complexity from the perspective of the PAR Holon Framework introduced in Chapters 1 and 2; that is, from the perspective of a whole system analysis or schema that forms a bridge between the syntax (i.e., expression) of a mathematical formalism and semantics (i.e., meaning) of its natural referent (see Fig. 4.1).

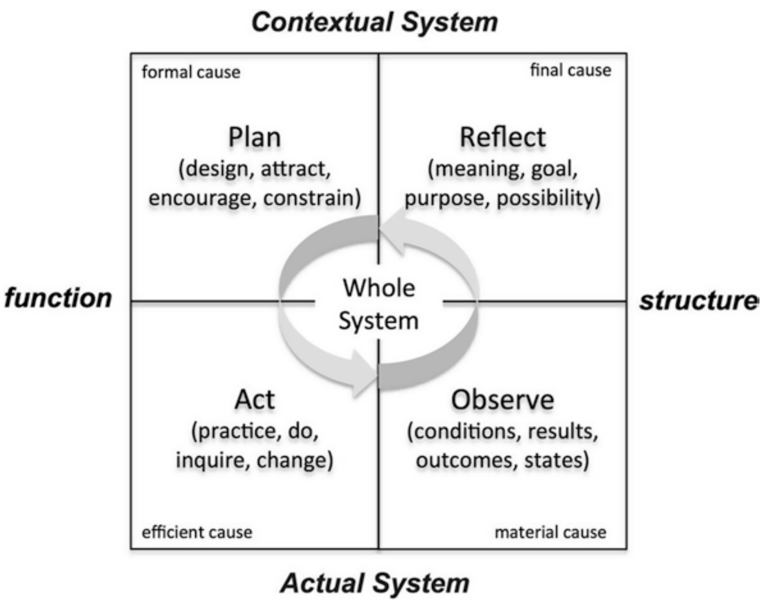

Fig. 4.1 PAR Holon Framework

Throughout this discussion it will be important to bear in mind a warning that Robert Rosen (1991) gave about this bridge; namely that it cannot be crossed from the "syntactic" side (although there are many attempts to do just that); it must be crossed from the semantic side, which generally means beginning with the natural referents. The systems researcher can think of mathematics as a language and scientific modeling as a process of writing a story in that language; a story that should have meaning, not just rules. In considering complexity it is not only impossible to expunge the natural referents, but their natural semantic qualities must be retained in order to cross the bridge back into mathematical formalism in a valid way. If the systems researcher does this carefully, the view of systems can be broadened beyond the rigid reductions of mechanistic/positivistic science and other *special case* views, to include aspects of natural systems communicated to the researcher by a full range of experience.

In particular, the PAR Holon Framework allows us to make some comments both about systems and about modeling. We will unavoidably touch upon some very fundamental issues in the philosophy of science and mathematics that arise in modeling complex systems and how they differ but employ methods of simulation, metaphor, and analogy. Issues about how modeling should or should not be done, what it is about, and its limitations, become critical as we expand into domains where exact modeling methods are no longer adequate and mathematically robust approaches for modeling complex systems are, as yet, experimental. For most of this discussion we will rely on the philosophy of Robert Rosen (1985, 1991, 1999), introduced earlier in this volume, most of which was about relational modeling. A brief background is in order before we begin.

Ontological Considerations

Rosen and his mentor Nicolas Rashevsky developed views of complex systems under a research program in Relational Biology between 1958 and 1998. The work has broad implications in the systems fields, and consequently many interpretations; however, the work has foundational value for all systems research (Rosen, 2012). In particular, Rosen presented two lines of argument: one based on modeling relations and the other based on efficient entailments in category theory. His ample hints at generality have stimulated attempts at synthesis and the possibility of articulating a rigorous basis for understanding whole systems. By extrapolating relational theory to holons and noting their strong correspondence with the PAR Holon cycle (see Chapters 2 and 5), we can present an analytical framework and new worldview in which modeling has a central role, emphasizing the need to couple or integrate models across four fundamental domains.

There are two keys to understanding the framework's implications for modeling. The main key is its abandonment of the purely hierarchical view of causation and adoption of a cyclical hierarchy (as represented in the PAR Holon cycle). The other key is to relate natural causality in the sequence that preserves causal order, so that four causal loops can be represented in a logically consistent mathematical formalism for analysis of whole systems. These two theoretical assumptions follow from the logic of modeling relations expressed as a four-quadrant framework.

Recalling Chapter 2, we can see modeling relations most readily in how science is done (i.e., research using the scientific method), but the modeling relation may also tell the systems researcher something about the organization of complex systems that allows us to do science. The methods of science have to do with encoding models and testing their decoding to get deductive causality (efficient action) to *commute* with inductive causality (formal inference) as well as possible. In plain language, the aim is to write models that perform like nature (including the nature of social and cognitive systems), using rules we believe these systems follow. If the encoding and decoding of a model commutes with the *natural system* in this way, that is, the model provides an accurate image of its performance, then we have a good model. It is no coincidence that the modeling process itself translates into our PAR Holon Framework, which has proven value in describing complex systems. This curious fact should get our attention, because it would be bizarrely improbable if there were not some natural basis for it. The proposition arises that perhaps complex systems are themselves organized as modeling relations, which then explains why it is difficult to model them. Such a suggestion might seem unjustified in currently accepted research; however, it represents the most general case that is compatible with (and generally reducible to) most other views.

The idea that something fundamental to modeling may in some sense be a general process in the organization of natural systems is a difficult turn for current science to take on all four wheels (so to speak). But we have been heading toward this curve steadily for at least a century. There have been many naturalistic and humanistic arguments for such a view in many disciplines. And yet, all of these arguments seem endlessly debatable because, as perceptual creatures, we can never know what lies beyond the subject–object relation; we are fully embedded in it. As physicist Niels Bohr (1885–1962) said even of quantum theory, it is impossible for us to observe nature, no matter how strange it may be, without conceptualizing it in the sensory and thus reduced terms of our everyday experience (Schlosshauer & Camilleri, 2011). The reader may appreciate that all of our impressions of the natural world originate in some kind of modeling procedure, whether done automatically by our organismic nature (somatically) or intentionally as an intellectual exercise (cognitively) resulting in mental models (Craik, 1943; Forrester, 1958, 1961). The argument that models are natural is also justified from the many centuries of intensive effort trying to formalize its alternative (that nature is somehow *given* in fixed forms and we are mere observers). Instead, we have come to realize, as Wheeler famously said, that nature has a "participatory" quality at its core (see Chapter 2 title quote, Wheeler, 1981, p. 194). We can no longer ignore this discovery and pretend to model nature without it.

However, it is also true that the more exact descriptions that have been confirmed in science, must also be explained by the proposed complex, participatory background, and in most cases retained within a complexified context. But there is no conflict; reduction is always a possibility. It is something systems can do (they can simplify) and that the systems researcher can confirm or reject empirically. The real point is that it is not the other way around: complexity does not come from its reductions. Rosen emphasized that reasoning to complexity from simplicity does not work; it must go the other way.

Paradox and parsimony, discussed in Chapter 2, are two epistemic principles that we can now rely on to justify inverting the mechanistic paradigm of nature to a complex foundation. Complex systems are paradoxical in a mechanistic world but mechanisms are normal in a complex world. The paradox is thus resolved in the most parsimonious way by moving to a deep model-based realism.[1] Adopting the broadest ontological framework is also a good idea because it is not possible to test the validity of theoretical ideas in science, like contextual relations, if they are not first given theoretical existence. As Einstein explained to Heisenberg in 1926, "Whether you can observe a thing or not depends on the theory which you use. It is the theory which decides what can be observed" (as cited in Salam, 1990 p. 99).

Relations Tell Us Why

If we ask the *why* of things, instead of reduced forms of *how*, the concept of natural law acquires a broader meaning as something that involves context-dependency (even in the mechanical case where the context of "natural law" is presumed to be unique). But when considering complexity, we have little choice but to think of some analogy to modeling in nature. It is fairly obvious to think of organisms in this way, as creating their own internal models, but it is also extremely useful in other cases where we simply do not know of a valid reduction. It is almost axiomatic that we cannot model formal differences in nature without having formal differences in science. For example, this is the reason there are wave and particle formalisms in post-modern physics, and the closest anyone can come to a *whole* description of a quantum system is to couple them.

In other words, if we can apply logic in the explanation of nature, then nature must in some sense *have* a logical aspect. Modeling is then the art of determining what that is. The debate in science has not been so much about the existence of order in nature, but about what kind of order it is, especially if it is simple or complex. Increasingly, physics is moving to the view of complex information or model-dependent outcomes in quantum processes and cosmology, even admitting an analogy to something "mental" (Henry, 2005). Rosen argued strongly that encoding and decoding of natural, internal models is a main characteristic of complexity, life, and social phenomena. There is evidence from many fields that something basic to modeling, and thus learning, is in the very organization of nature. Of course, it has been at the core of human and social sciences for a long time.

But owing to how modern science developed, it was difficult to think about models *in* nature despite the many arguments for it. Rosen (1991) made the argument that models are in nature, but that is a different question than asking where the encodings and decodings exist that create and apply in models. On that question, he was relatively mute, as they are neither a part of the observed system (human or natural) nor a part of the encoded model used in science. But they happen and are apparently something that both humans and nature can each do in their own way. The PAR Holon Framework that we have discussed so far incorporates the encoding and decoding process to describe the model building process itself. It is actually a

[1] One somewhat deeper than proposed by Hawking and Mlodinow (2012).

more primitive modeling relation that allows us to do science (that composes the scientific modeling relation) as opposed to the relations between an encoded model and various phenomena that are the contents of science.

Clearly, if nature is also doing this kind of modeling relation, it would be extremely difficult to get our models to commute; meaning, to give exact results. We would be in the situation of modeling the results of a separate and often hidden modeling process, which is a prospect no scientist wants to consider without having it thrust upon them by the evidence. However, that is the situation science now faces in most disciplines dealing with true complexity (including life, consciousness, quantum and cosmological physics, and of course all human systems). The fear this prospect raises is whether science itself will be damaged by the introduction of subjectivities. Most scientists agree that, if we go there, the metaphysics (assumptions of a theory) must be done carefully to achieve a more general view that is nevertheless consistent with what we have learned so far, even if approached from a different direction. Perhaps the strongest point about this was made earlier that we can only study what we represent by our metaphysics; the sense in which theory decides what we can see.

There is one alternative, which is to retain a certain agnosticism about what nature *does* or how it does it, and to think of our models as describing only human experience of other systems. That is, recognition of the many ways that one can interact with complex systems. This is the road taken so far in most of the social systems sciences, based more on the dichotomy of self and other, as opposed to existence and explanation; perhaps arrived at because positivistic methods were so arrogantly exclusive of constructive processes and uncertain outcomes undeniable in human experience. The reasoning from this counter-positive view is that working from what we can know—human experience—what is the sense in speculating about what nature does as compared to looking for regularities in our interaction with it? Indeed, the current trend even in physics is to abandon *naturalistic* explanations in favor of instrumental calculations, that is, “shut up and calculate” (Mermin, 1989, p. 9). We will explore this view somewhat, as well as the naturalistic view, to see in depth how they can be combined.

Formalism

The first thing we have to understand about modeling is that models are *formalisms* that a system obeys as a result of local dynamics and contextual *shaping* (e.g., selection, scaling, constraint, or topology) of those dynamics. In complex systems, these two categories should, most properly, be modeled separately and then coupled. Conflating them reduces them and destroys important aspects of the complexity.

The overall model may be complex or simple. In either case, it is intended to replicate not just the behaviors of a system, but also the causes of behaviors (entailments) and how those causes are conditioned by contextual factors (formal boundary conditions). Therefore, models are really hybrid formalisms, one aspect being about the dynamics and another aspect being about the space in which the system exists and operates. This fact is often overlooked in modern science in assuming a common formal domain in which scientific models can accurately describe unique natural laws. But, for example, in order to explain relativistic dynamics, dynamical models of motion in space–time must be scaled by models of the curvature of space. Such contextual constraints are expressed by Aristotle's "formal cause," which in the Holon Relational Framework acts hierarchically on efficient cause (and consequently on its maps); for example, as topology or other boundary conditions delineate dynamics.

Re-admitting formal and final cause to science has been one of the main obstacles to transcending our mechanistic worldview, or machine metaphor. Here we take a direct (naïve) view of formal and final cause[2] as the logic of the modeling domain in general, meaning the logic of scientific inference, and perhaps Bohm's (2002) "implicate order" in nature. Rosen's scientific modeling relation applied to human activity thus becomes a special case where evolution has enhanced an otherwise natural process (as in all cases of evolutionary phenomena). This view accords equal general status to all four of Aristotle's causes and leads to the highly simplified graphical framework for visualizing the relation of causes (Chapter 2). Thus, we address complex modeling beginning with the most general schematic view of it.

The second thing to understand about modeling a complex system is that it does not attempt to describe everything about a system. Instead, it attempts to replicate something that is true of the organization of a system (as confirmed through empirical evidence and inference). In this view, it is not possible to have a model of everything. The self-similarity principle on which this framework is based means that there can be no *largest model* and that not all functions the systems researcher might need in order to describe a system are *simulable* (i.e., calculable by a Turing machine). Nevertheless, there can indeed be a *model of anything*, in the sense of modeling the natural organization of systems by inferring how causality must be generally organized. In a sense, the PAR Holon Framework proposes to be such a model (subject to the usual caveats in science). The false hope, still in our recent memory, that mechanisms (which are restricted to simulable functions) would suffice for such a framework should not discourage us. It can serve as a reminder that testing is necessary to know when a paradigm must be expanded to resolve discovered paradoxes.

In a pragmatic approach, the systems researcher might focus instead on human interactions and their results—a differently focused set of models such as perturbation models in physics, which are nevertheless very suited for quick results in complexity fields. It says: "If we do A, we get B." If B is what we wanted, and it can be reliably obtained, we say the relation between A and B is a useful model. How we describe that relation is up to us—a constructed reality, heuristic, or instrumental

[2] More traditionally, final cause is associated with the end of a material process, leaving some vagueness about how it may subsequently become an actor, as it does in the holon cycle.

calculation. The method lends itself to a selection of theories and practices in something analogous to adaptive fitness (Yearworth et al., 2015). It is formalized by "linkage propositions" between observable behavioral *isomorphisms* that have various existing theoretical descriptions (Friendshuh & Troncale, 2012; Troncale, 2006). The result is something instrumentally adapted from known isomorphisms, without necessarily claiming to have a general ontology for nature, unless it is such isomorphic linkage itself.

The fact that these two modes of description can converge on similar results is quite amazing, and possibly profound. It is also the first insight of science that human constructed concepts about nature can actually agree with what nature does; meaning, nature is knowable through human experience. It may also be a reason—intuition and imagination are essential qualities of the scientist. But, of course, the method of testing that knowledge has always been the issue. If we were to try to explain this amazing coincidence, we might look at two well-established facts. One is that humans evolved from nature: Is it then so surprising that people can have natural ideas? The other is that we have no means of knowing what nature is doing except by interacting with it: Is it not to be expected that even the best empirical models will thus have anthropocentric aspects? In the end, the two approaches may come together, if they are each done carefully. Meanwhile, they represent two different approaches to the same end. The relational framework applies to both approaches.

However, relational modeling began from the realist side, even though it ended up describing a constructive process. The pragmatist might accept the PAR Holon Framework for working purposes while the realist might consider it our current best meta-model of reality. The value of this assumption in the realist paradigm is not to establish dogma, but to ensure testing, always with an eye to something better or to discovery of a fatal paradox (as that which led to relativity theory, see Chapter 2).

In use, our framework is meant to be both holistic (capturing whole qualities) and analytical (allowing knowledge decomposition); in other words, it allows us to describe whole system organization in terms of self-similar component wholes (the idea of taking wholes from wholes). Ideally, it is meant to exemplify, perhaps archetypically, a fundamental unit of nature. The main quality of the framework that allows this claim is that it has an identity loop, thus giving mathematical rigor to the concept of a system. But, while following the realist paradigm of *discovering* what nature is doing, it recognizes that constructive relation is most likely what nature is doing. Thus by distinguishing formal domains in relation to phenomena, the systems researcher can remain open to many kinds of formal description that may be necessary or may simply represent the state of our knowledge. But to explain the path leading to this combined metaphysic, we need to back up a bit, to review what modeling has been about and what its main limitations have been. Hopefully the student of complex modeling will see many images of various modeling approaches along the way.

A General Theory of Modeling

Rosen (1993) expressed the view, as a mathematician, that the theory of categories is in essence, a "general theory of modeling." It is based on mappings within and between categories, which are sets of objects and mapping functions with a topological order.[3] The topological order defines a parameter space, by which we mean a generalized phase, state, factor, character, coordinate, or measurement space within which a system exists and operates; for simplicity we will call it a system *context*. Without considering the nature of this context, we cannot create a model of a system, because in a significant way any system we observe must share the topological properties of its measurement space. Perhaps the most well-known example is the shape of space–time; yet, there are an infinite variety of nonlocal factors (that do not specify space and time coordinates directly). They can describe suitability conditions, such as potentials, for local existence of some material object or phenomenon. Thus, existence and behavior are co-arising but non-reducible aspects of nature that make all systems fundamentally complex.[4]

The space–time context seems to be unique in our experience because it separates discrete events. This gives us the experience of objects and a physical world. It is unified by having a common history and thus a temporal dimension. Its exclusivity between events or objects is largely what makes it seem "real" to us, where a thing has its own location and physical boundary ("two things can't occupy the same space at the same time"). That is what Rosen (1991) meant by a system becoming "realized" (we will use the more specific term *actualized*, because contextual potentials should also be thought of as *real*).

There is also a good example of this kind of distinction between actual and potential in ecological niche modeling, in which species dynamics occur in geographical space with discrete measurable properties, and concurrent conditions for existence occur in ecological niche space. The relation between contextual suitability and actual dynamics results in adaptation, survival, and thus evolution (Chase & Leibold, 2003).

Mechanistic science, on the other hand, has always had a problem with contextual effects; for a while it depended on getting rid of them. As dualistic thought rose over the past four millennia natural philosophers were more or less forced to create a practical division between science and questions of contextual existence, largely to distinguish descriptions of behavior from issues addressed in religion. Dualism attempts to separate unknowable or mystical existence from knowable phenomena. Modern science was thus freed to focus on behavior after existence; that is, *reconfiguration* given pre-existing and conserved absolutes. But since science began asking questions about life, evolution, consciousness, quantum and other complex

[3] The term "order" is used as opposed to the term "structure," which is more accepted by mathematicians, to avoid conflation with its meaning as a material structure.

[4] Attempts, for example, to explain evolution in purely mechanical terms, consistently suffer from semantic incompleteness in the same way that Gödel's definition of incompleteness requires semantic referents in number theory.

phenomena, the effect of system origins (or novelty) in the present has become an unavoidable issue, especially considering anticipatory systems, which are adapting their behavior and existence to future possibilities.

In ancient times, the Vedic philosophy of *advaita* (nonduality) resolved the origin problem by seeing nature as a complementarity between existence and nonexistence (a nondual whole); essentially, a self-creating holarchy rather than a creation hierarchy. Since ancient times, the Vedic worldview included the idea that "no-thing" is as filled with causality as "some-thing." "Thing-ness" is a property of measurement space because it requires discrete coordinates; whereas "no-thingness" may be equally existent, but as yet without locality (i.e., nonlocal). These are potentials waiting to be translated into sensory phenomena through dynamical processes. The idea of "latent" potentials is apparent in the complex human world (Edmonds, 2001; Landauer & Dumais, 1997; Poli, 2011). The mechanistic view (machine metaphor) is a special case where existence and behavior have the same laws; that is, they seem to exist in a pre-defined context.

Nevertheless, it is hard to transcend the simplified view of perceptual objects. Even symbolic representation tends to be irretrievably about *things* rather than abstractions from a more complex reality (as in the ancient concept of *maya*). For example, the idea that something and nothing are complements shows up in the concept of zero, which also came from the nondualists. Only in the last century of post-modern science are scientists returning to such concepts, for example, in an energetic quantum "void" or "vacuum" from which measurable objects emerge. Even our concept of linear time and historical origin is being challenged (Masreliez, 2010, 2012; Unger & Smolin, 2014).

In its history, science has avoided considering variation in the formal cause (contextual) domain. As a result, researchers could separate questions of origin and conditions for existence from questions of systems behavior, focusing on the later. And yet, the complexity problems encountered in physics and biology are undeniably associated with the connection between these two. Implicitly, the PAR Holon Framework tackles that problem directly, representing both actual and formal worlds as complements of each other. When modeling, we are really modeling two domains; one that specifies the dynamics of phenomena and another that specifies existence of phenomena. The key to developing general modeling approaches for complex systems is to relate these two; that is, coupling models of dynamics with models of formative contexts.

Complex Modeling

We can now provide more detail about how to translate modeling relations (discussed in Chapter 2) to an analytical method for modeling whole system organization. Clearly, models restricted to either the actual system or the contextual system cannot capture complex relations. However, the framework might suggest a way of modeling complex systems by relating contextual and actual system models in an iterative cycle that can be infinitely decomposed into self-similar cycles. Our intent is to model the way context modifies and even directs mechanical processes, and the way mechanical processes establish contexts.

Referring to Fig. 4.2, we can define four basic kinds of modeling associated with each of the four causal quadrants of the framework.

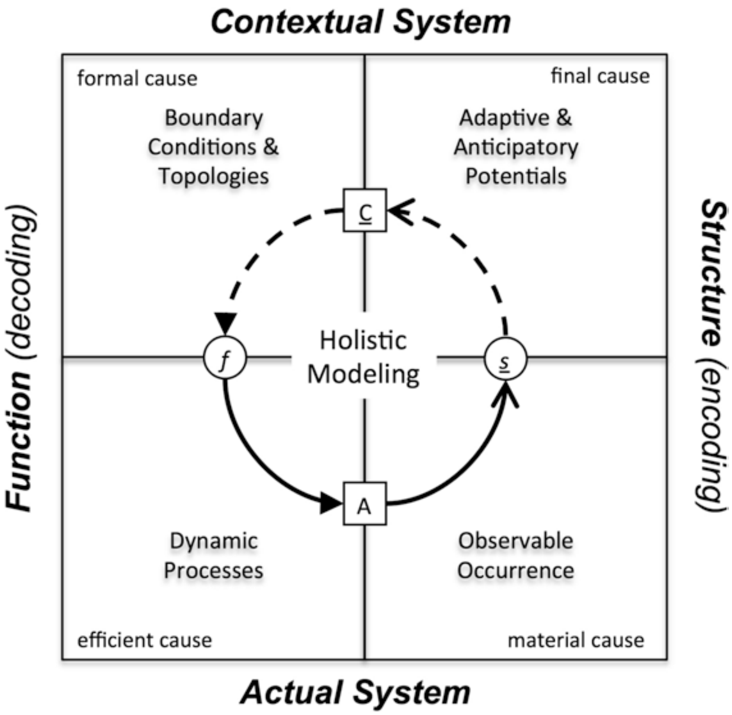

Fig. 4.2 Modeling framework

Recall that, in the Relational Holon Framework, science can treat these causalities as natural because—and only because—they constitute a cyclical whole, not a linear hierarchy reaching out of nature. It is not generally appreciated, however, that each of these kinds of model can be modeled; that is, each of Aristotle's causalities can have its own scientific modeling paradigm in relation to the others, as follows (numbering traditionally from lowest to highest in reverse order of their operation):

1. Observed states and occurrences
2. Dynamic processes and emergences
3. Bounding conditions and topologies
4. Anticipatory exemplars and memories

5. System identity and organization (cycle of the above four)

The first four kinds of model correspond with the four causal quadrants in the framework. They also roughly correspond to the four definitions of the term "model" given in the Oxford Dictionary (McLachlan, 1999). McLachlan (1999) explains that models can also be grouped into two basic kinds of information: about function and about structure. These are the epistemological relations between categories associated with information encoding (1–4) and decoding (3–2). Two other groupings are possible, which are the contextual (4–3) and actual (2–1) systems in the framework (the ontological categories). Coupling those models takes us to the fifth level, which is represented by the framework itself. Modeling at the fifth level is about system organization and identity, which includes learning, adaptation, wholeness, life, consciousness, and so forth. We will discuss modeling primarily at this level, which is the holon. Armed with an understanding of these basics, systems researchers should be able to see many kinds of analytical constructions, although we will give some basic examples.

First we should note the good news, which is that there are multiple methods to do most of the quadrant models needed in this schema. Next, we examine each of the five levels.

Data

There have been tremendous advances in observational and informatics systems including the web and associated tools for data mining, analysis, and modeling. Interactive and participatory methods of observing experientially or even constructing realities are well developed. In this quadrant, systems researchers are collecting, storing, and processing data, then applying models to define objects, properties, and patterns and to infer structure of observables. This is the most defined of all the quadrants.

Dynamics

Dynamical modeling is well developed from modern science and humanistic research. From physical dynamics to social dynamics, we have a plethora of tools. More work is needed on emergent phenomena, however; that is, new conditions or systems that may arise without a known process or predecessor. In particular, emergence implies non-mechanistic origins for which systems researchers need to link the emergent phenomena with formal potentials (see next section) that exceed mechanistic limits. Network analysis is another approach that combines dynamics with complex topologies and emergent contexts. There is a lot of complexity research going on in this quadrant mainly because traditional science tries to conflate all the higher causes into efficiencies or their uncertainty; and of course the recommendation here is to develop them in their own domain, using the Holon Relational Framework. To a large extent that has been the goal of the entire field of system dynamics.

Potentials

Probability models have been the main approach for modeling potentials. In most cases, they are actually used for data modeling, but in some applications, experimental research takes place to infer actual potentials. In environmental science, business, and other fields, scenario-building helps define the potential landscape for system outcomes even where probabilities cannot be defined. The search for "tipping points" and "attractors" in complex systems, the effect of pattern, design, memory and planning, and models of topological spaces occur in this quadrant. As mentioned previously, it is important to do more thinking about real potentials for new dynamics in natural and human systems, rather than just statistical descriptions of actual conditions or probability of knowing something that otherwise has a deterministic origin. In social and complexity science fields there is increasing attention to emergence, autopoiesis, nonlinear processes, and other forms of context-dependency, but we need a better theory of this domain and better modeling tools.

Possibilities

Scientific models are least developed in this quadrant, mainly because final cause was avoided in science. In contrast, there are many approaches in the social and complexity sciences to understand constructive processes, goals, visions, and creative opportunity. Traditionally associated with the idea of "purpose," this domain was thought to be unapproachable, until the research community had no choice but to approach it. It bridges to spiritual and theological concepts of immanence, but as described extensively in Chapter 2, it is better conceptualized as a natural, memory-like cause in cyclical relation with the others, translating prior exemplars to corresponding potentials for self-similar emergence. Evolutionary and cognitive models are in this quadrant, including new research on niche construction, selective processes, and semantic systems; but it is the least defined of the four (Odling-Smee, Laland, & Feldman, 2003). One approach that could greatly advance in this quadrant is adaptive niche modeling, which is (in relational theory) the inference of potentials from exemplary occurrence. Presently, what often passes for niche models are various data models that attempt to estimate actual occurrence without considering potential and dynamics (Elith & Leathwick, 2009).

Relations

Developing a general system theory (von Bertalanffy, 1968) has been a dream in the systems sciences since its inception. As with the much longer pursuit of holism generally in science, it has enjoyed times of favor and disfavor. The history of holistic ideas in natural science is a fascinating one (for an extensive review, see Hardon, 2008), and yet even a generally agreed working theory has eluded us.

Consequently, the systems sciences have a plethora of theories, philosophies, and practices (see Chapter 1). If we are to develop a whole-system theoretical view as many would like to see (Rousseau, 2014), it is perhaps axiomatic that we will need some agreement on how to relate the two domains described here as contextual and actual, between which we find great divisions in and between science and society, as classically presented in C. P. Snow's, *Two Cultures* (Snow, 1993). Generally speaking, the study of living, cognitive, ecological, human, and social systems unavoidably reaches into the contextual domain and—one way or another—complexity studies must find a way to cross that boundary. The U.S. National Science Foundation's State-of-the-Art strategy, for example, centers on the idea of "coupling natural and human models" (which crosses the same basic divide; Alberti, Asbjornsen, Baker, Brozovic, Drinkwater, Drzyzga, … Urquhart, 2011), the former rooted in state and dynamics and the later rooted in construction and potential.

Modeling in the higher cause categories (contextual causes) is certainly possible in just the same way that models of mathematics itself are not only possible but characteristic of the field (Rosen, 1993). The *noumenal* domain (taken less absolutely than Kant's view, as a complementary aspect of the "thing itself") admits to models just as the phenomenal domain does. Systems researchers may be tempted to think that because modeling in the natural sciences tends to follow more exact laws and dynamics while modeling in the human and social sciences tends to follow construction and context-dependency, they are about different systems. Such characterization is unfair to both fields, which today are required to deal with whole systems and comprehensive problems. The problem is not their difference but their mutual conflations, where the methods of one domain are used inappropriately to describe the opposite. So, the bad news is that, while there are many tools, they have not been integrated into a natural modeling framework, except on a highly ad hoc and compartmentalized basis. The framework allows systems researchers to preserve the distinction between domains and to specify how their distinct models can be properly related.

Coupling Models Relationally

As mentioned earlier, mechanistic models are valid within an unvarying law-like context. Therefore, the key to using a mechanistic model in a complex situation is that the causal loop must track contextual changes at the same rate as the mechanistic model tracks the dynamics (or close enough to minimize error). That, of course, is no problem if the context does not vary. But if the dynamics or other systems cause the context to vary, and vice-versa, the model has to track it. As an analogy, it would be as though every turn of the steering wheel of your car also changed the direction of the road in a nonlinear way. No mechanistic model of past behavior can anticipate the turns needed to stay on the road. The problem is not solvable in predictive ("closed") form because of the nonlinear relation between the two systems (road and car). But, if the models are coupled in a fine enough iteration between system and context, they can be kept in closer correspondence making the appropriate adjustments. In doing so, systems researchers will likely discover some general patterns, attractors, and other behaviors. Thus, the aim of relational modeling is to understand the organization between these two domains to track the problem real-time, build scenarios, or accumulate other forms of experience. This car example is very much like what characterizes the famous n-body problem, in which the trajectories of three or more independent orbital bodies cannot be exactly specified owing to their modification of the gravitational context itself, as they move under the influence of their own gravity field.

There have been plenty of alternatives to mechanism that generally fall in the contextual system domain and are used to modify mechanistic predictions, including nonlinear and probabilistic models. They are even proposed as alternatives to mechanistic thinking. The modeling framework (Fig. 4.2) is meant to be general to all such approaches (it only specifies the proper relations between deductive and inductive models, not how systems researchers might wish to approximate those models and relations). The approach here is, to some degree, what is already being done more or less intuitively. It relates the four kinds of models, although more distinctly and with greater awareness of their relational unity. In short, it relates them in a natural way without conflating them.

There are many intriguing possibilities we cannot yet assess in the idea that all natural phenomena might be described in terms of such relations themselves. That is, the implication of any general theory and what was thought about mechanism; but certainly, there is an economy between these two views of nature given that, realistically, working with systems involves some experimentation in how to combine their complex and simplified aspects. Our present understanding of the coupling between human and natural phenomena in socio-ecological systems, for example, is very poor and a high priority for research (Alberti, Asbjornsen, Baker, Brozovic, Drinkwater, Drzyzga, … Urquhart, 2011). Most current thinking is to link mechanistic models of physical systems with qualitative models of human, social, or cognitive dimensions through inputs and outputs, a limited strategy at best (due to the granularity of their interaction, as mentioned earlier). Developing integral models along the lines described here will take considerably more work. For now, coupling what are essentially simulations in each quadrant, may be the best we can do. Otherwise, systems research is faced with inadequate alternatives: to accept the uncertainties of mechanistic models or the subjectivities of humanistic approaches.

Mathematical Basics of Relational Modeling

We can now give a brief and basic idea of the framework's holon logic using the most basic elements of category theory. The first step is to define terms specifically for this purpose. The following is meant to be a generalized notation that can get us started.

The basic concept of *entailment* is quite intuitive. Entailments are morphisms (functions) operating on elements of a set resulting in mappings between elements and between sets. Categories comprise such morphisms and their mappings. In our framework they incorporate the two upper and two lower adjacent quadrants. In the traditional view the efficient entailment is a mapping in which a function drives a logical association between a prior condition and a later one. It is usually written $f:(a,b)$. This notation works for many problems, but it may be more generally consistent with what we now know about phenomena to say that *b* is *abstracted* [5] from the actualized system A, thus not implying that it was pre-existing. Category theory allows this interpretation, but it is not usually stated. In any case, the material map is measurement, but if we leave topology to other causes then each measurement is explicitly a new measurement taken out of a complex system that may not even have the measured property between measurements. How useful it is to think of an element as belonging to a pre-existing set or as created from complex possibilities (as appears to be the case with quantum particles), depends on the application, but a general approach should be based on the most general case.[6] The map may be drawn as a function (lower case symbol) operating on a Set (upper case symbol) abstracting an element (lower case symbol); that is $f:(A,\underline{b})$.[7] This notation does not skip the causal loop of the holon as the former notation does, and is thus more precise. If we use the former, we are employing a summary of effects between actualizations and we thus miss the opportunity to consider the effect of contextual changes.

Next, we need the converse of abstraction (or deduction), which is inference (or induction). This is a complete reversal of the efficient entailment. Whereas getting a state from system interaction is an abstraction or measurement, getting a function from a system context is a "de-abstraction" or "inverse measurement" (Rosen, 1991, p. 60), which may also be referred to in category theory as an "inverse" or "converse" entailment (A. Louie, personal communication, February 24, 2016). That is, with the efficient entailment we have a way of imagining how a function produces a measured state of a system, but we do not have a way of imagining how a state produces a function. It seems inescapable to suppose that they do, somehow. So, we introduce a mapping initiated by an abstracted physical state or structure (which becomes final cause), introduced into a context, which produces a new function. For example, a chair used for sitting in the context of one's home would evoke different functions in the ocean, perhaps as a substrate for barnacles or food for microorganisms.

[5] Abstraction means "taking away from;" for some strange reason its colloquial meaning has gotten inverted to imply something other-worldly, whereas it really means something removed from the system. Rosen often said there is nothing more abstract than a measurement.

[6] It is certainly possible to discuss mappings between existing states, but there is still an implicit contextualization involved in producing the successive states.

[7] Underlining abstracted structures and contextual systems helps distinguish these symbols from functions and actualized systems.

A physical structure is thus responsible for inducing a contextual map that results in a function or behavior, just as a function is responsible for producing a material map that results in a physical structure or object. Here we suggest writing it as *b:(C,f)*, where *b* is the result of a material map, *C* is systemic context, and *f* is again our concept of an efficient function. We thus explicitly introduced context as a necessity in the general view of causality; as necessary, in fact, as is the material side of a system, the interactive system.

There are many possible entailments and relations that can be made out of these primitive mathematical elements; possibly all that we need to model complex and simple systems. Again, the existence of a contextual mapping is not a problem for mechanisms themselves, it is only that they occur in an invariant context.[8] The approach is least presumptuous (and thus most general) in saying that material maps are the results of interactions (which are also measurements) taking place in a topological context that decides the *location* of those abstractions and their association with objects, and that functions are the result of a formal map induced by a *final* condition (object, state, structure, etc.) via context. The former is an efficient entailment; the latter is a final entailment. This, unfortunately, is a new concept that will require some time for adoption, but, in any case, it seems compatible with standard relational theory.

In that case, the roles of final and formal cause as contextual relations are implied by the nature of functors and the mathematical structure of homomorphic sets. In that approach, the role of context is part of the algebra, which can be quite daunting to learn (but certainly worth the effort). We cannot say at this point that the two approaches are equivalent, but they seem compatible and there are probably advantages to each. The method presented here is to represent contextual entailments graphically, thus making them explicit rather than implicit. The graphical approach implies holons, which allow us to visualize what may be happening on the contextual side.

Figure 4.3 shows both of these forward and inverse entailment maps in graphical form, along with a legend to interpret the symbols. In the graphical form we use a dashed line to distinguish the contextual map. An open headed arrow indiates a structural encoding (abstracted state entering context), and a solid headed arrow indicates a functional decoding (model dependency). Encoding and decoding, which occur between contextual and actual categories, are technically called "functors" in category theory. Their job is to translate the full entailment of each category into the other in an information-preserving relation.[9] Thus, they bring the categories of entailment (interactive causality and contextual inference) together. It also makes

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[8] One can now argue that there are no invariant contexts, just as there are no truly closed systems; but that begs the point that such approximations are useful.

[9] The traditional language is "structure-preserving" which creates confusion with the natural meaning of structure. However, since we can see in the framework that functors are information relations (encoding and decoding), we can suggest that generally they are information-preserving transformations.

sense in many fields, such as ecology where these words are a standard but poorly defined dichotomy. There are so many equivocations on these terms, however, that one must be clear in their usage.

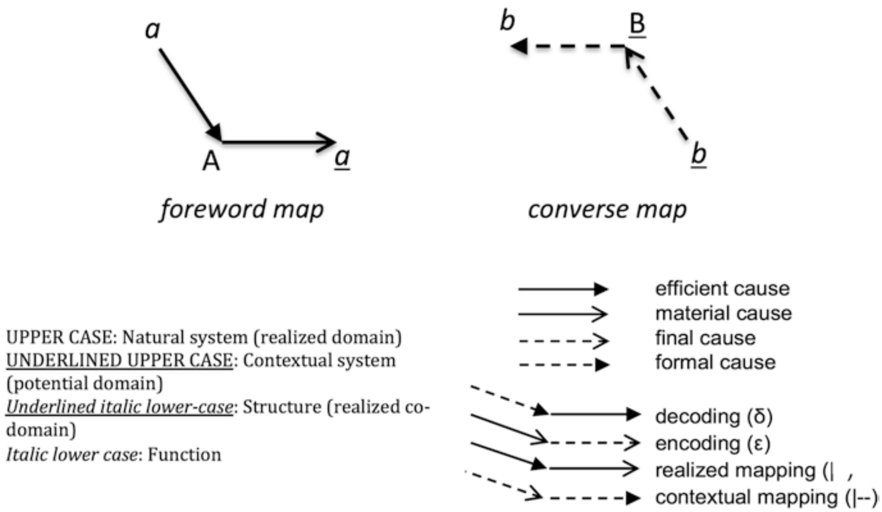


Fig. 4.3 Foreword (deductive) and converse (inductive) entailments for identity [A]

Once we have these mathematical objects, we can describe a contextual relation (Fig. 4.4). It is easy to show that such relations explain the scientific modeling relation described in Chapter 2, where the contextual side is actually in the position of encoding and decoding.[10] It represents a unit of holistic analysis[11] at one level with deductive (efficient/material) and inductive (final/formal). The encoding and decoding information relations can also bridge between holons. This gives explicit mathematical detail to the idea of "model-dependent reality" as a general phenomenon.

[10] The letter symbols in the diagram are the same as described above.

[11] We can thus remove the self-entailment arrows in the original modeling relation, because in this view they are explicit compositions.

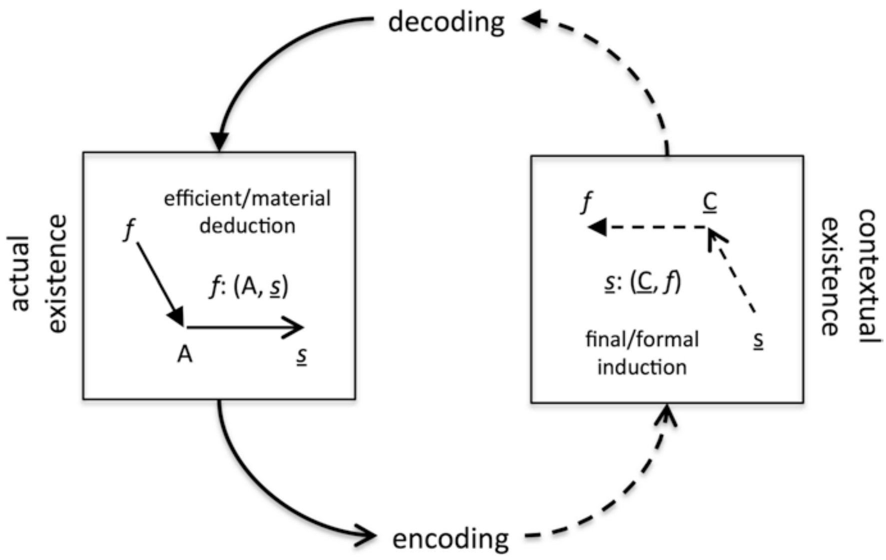


Fig. 4.4 Contextual relation

We can also label natural identities we want to keep track of with different formats of the same letter as shown in Fig. 4.3. This is important in order to track which contextual models belong with a system's identity. The analysis will allow us to relate models associated with the system identity with external contexts, but there may be a difference depending on which governs the system first. For example, organisms behave and evolve within an environmental context (they have behavioral and selective models), but aspects of the environment are also encoded into the organisms internal models. This is to say that there may be a difference depending on the order in which relations are applied, differences in the strength of mappings (e.g., as in suitabilities, probabilities, or via inhibitors and catalysts), and complex differences in context.

As discussed in Chapter 2, we cannot actually have a closed loop of efficient causes without an inductive map and intervening context. In a world that is formally defined by one self-consistent context for discrete temporal objects, it is paradoxical to have two things deducing the occurrence of each other; it violates the temporal context (history) of their domain making the relations uncertain. Such loops cannot technically exist in mechanistic topology, where they are like Escher's (1898–1972) diagrams; but they are nevertheless characteristic of quantum systems, dissipative systems, open systems, living systems, cognitive systems, and so forth. The paradox is resolved if we assume that the universe is relationally complex. This was one of Rosen's (1991) ways of saying that the world is not mechanistic. Even adding more intervening dynamics (more hierarchical efficient maps) cannot model complexity. In holon analysis, we take the next step of making inferences about context. We have already made the first inference that they exist; adding the contextual map, so closed loops of causation can by described. Additional contextual inferences are then possible.

Contextual analysis is a major advantage of the relational approach. For example, if origin and behavior represent two complementary contexts in a 2nd order closure (see Chapter 2) we might want to think of them as phenotype and genotype. In that case the system requires entailments with the environment. To get them we need more sub-system models in the system, and the easiest way to get them is to combine existing models. When this is done to get the needed environmental entailments one ends up with a 5th order closure, which is the contextually expanded form of Rosen's M-R system diagram—his template for life. Since they are so important, here is a quick look at how contextual relations work.

Figure 4.5 shows a contextual composition of two holons, that is, the union of two contexts. Recalling from Chapter 2, we can have two contexts in a 2nd order closure, but that only relates to encoding (final cause) or decoding (formal cause), not both.

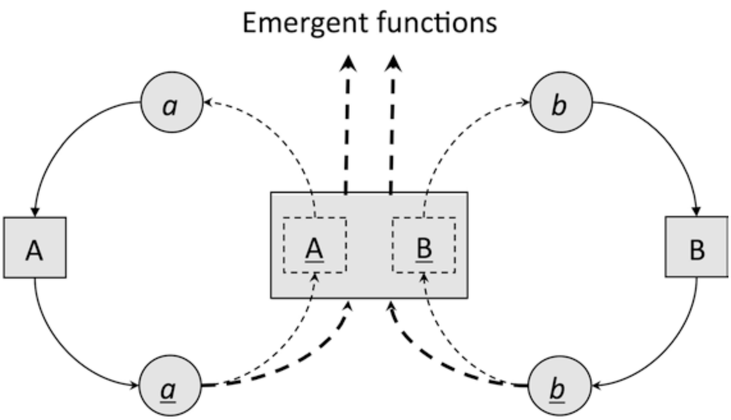
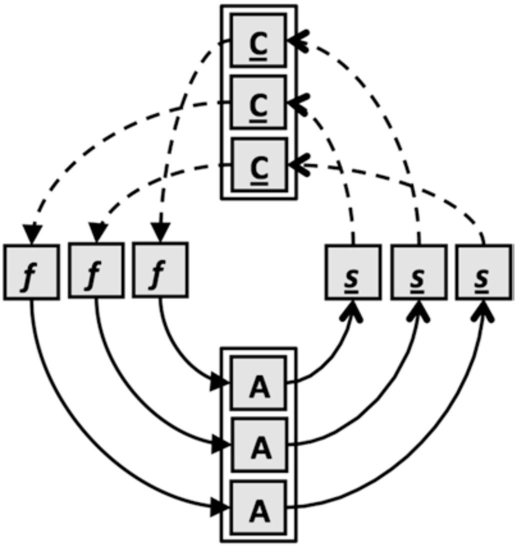


Fig. 4.5 Contextual composition of two Systems (A & B)

To relate both we need an additional context otherwise a two quadrant closure of two holons merely forces the two systems to reorganize into two separate systems. But, if a third system forms from the union of the first two, then the original systems can be preserved as a third order closure with contexts fully shared (Fig. 4.6).

Fig. 4.6 Shared context in 3rd order closure



The third context can then find actualizations; thus, the situation explains emergence as the union of two holon contexts. As suggested earlier, logic on the contextual side is qualitative in nature; it is that of categorical syllogism—such as the Venn diagrams. By applying that logic in contextual topology we get results that are just as mathematically sound as results of quantitative mathematics that apply to discrete entities on the actualized side. However, in contrast, conclusions on the contextual side are about combinations of co-occurring potentials, qualities, types, and so forth. We learn how many kinds of system there can be in a situation; a procedure that was used, for example, to post-predict that there should be three fundamental kinds of M-R system (basic kinds of life) with specific qualitative characteristics (different life strategies). That prediction was as observed in the biological world. The three types and their characteristics are *Eukaryota*, *Bacteria*, and *Archaea* (Kineman, 2011). The causal organization of these three, which is determined by contextual combinatorics, makes many predictions about behavior and capacity for further development, explaining, for example, why Eukaryotes developed organelles and so many more complex forms than the other types. Such results are speculative tests at this stage, but indicative of the potential of relational analysis.

With these rules and constructions we have a way of analyzing whole systems in terms of whole systems rather than "fractioning" systems and destroying their identity relations. In fact, a major goal of this analysis might be to find system identities and study the conditions affecting them. For example, a stable identity probably has much to tell us about system sustainability. The theory also provides a foundation for re-thinking many concepts in physics and cosmology having to do with the nature of the universe. System scientists should not be shy to pry into those fields because if, as we suggest here, the road to a science of complex systems lies in reformulating our worldview, that worldview applies and must be tested in all fields.

Certainly physics, because we accepted it as establishing our view of reality, has never been shy about testing in other disciplines.

Logically, there is another kind of third system that can be formed by the combination of contexts, which is their intersection. Whereas the union of contexts is associated with emergence, as described above, the intersection establishes a common reduction. It refers to what both systems have or can establish as a common formal reference system. It means that two systems that may be uncertain in their mutual measures in some coordinate (an uncertainty principle), when locally interacting (what we mean by interacting in a set of coordinates that define "locality") will necessarily establish a common frame of reference, that is, "local phase space." Unlike the case of emergence, this defines the common reduction of both systems. There is no general reason why both processes would not happen, perhaps suggesting both an increase and decrease in entropy that sums to zero (or the background value of a more general system) universally. However, if we are involved with the systems interactionally, we are also committed to the view from a common reduction, because interaction establishes that reduction, being a common property of both systems. These speculations need to be explored if for no other reason than to test logical consistency of the theory.

There is a great deal more that can be learned from the relational perspective. However, the purpose here was to show in some sufficient detail that there can be a rigorous and objective scientific analysis and modeling approach for complex whole systems, based on modeling relations. Thus we have gone from frameworks for organizing whole system thinking and research in Chapter 2, to the possibility of true models reflecting, in the Rosennean sense, an attempt to duplicate the *way* in which complex nature works, not just what it ends up doing.

Modeling vs. Simulation and Analogy

Recall the opening of this chapter—Rosen's (1993) description of modeling as associating formalisms with external referents. In addition, Rosen wrote: "If it is not done carefully, the process itself creates artifacts" (p. 360). He obviously had a flare for understatement, because one of the artifacts he described in great detail was the entire machine metaphor in science. This came under the heading "Good Mathematics, Bad Models." We must not forget that models are both practical tools and monuments to imagination. What they are certainly not is the thing they model; and for that very reason they are part of our constructed reality while serving as our best pointer to what we believe is real.

Rosen (1993) drew a sharp distinction between a *model* and a *simulation*, claiming that what passes for complex modeling these days is really "complicated" simulation. He emphasized that complication is not complexity. The difference is that modeling should reflect the entailment relations of the system being modeled. Gödel's incompleteness proof was about the inability to expunge semantics (natural referents) from mathematics, to have a complete and self-consistent syntax for natural phenomena, which was precisely the aim of Hilbert's (1862–1943) "formalization" program (Zach, 2007). The idea was to reduce number theory to fully computable operations. Such "efficient" operations, according to Church's thesis (Rosen, 1962), were expected to be able to provide a theoretically complete description of nature. But for that to be true, everything in nature would, in principle, have to be computable. Rosen very strongly rejected that possibility, by definition.

Rosen's later argument was that if efficient processes are not sufficient to model number theory, how can they be sufficient to model nature (Rosen, 1993)? Accordingly, they should not even be called a model. Models should reflect the actual entailment relations of nature (or even number theory), both of which are broader than computable "efficient processes." If the natural system being modeled is complex, efficient processes are too much of a restriction; in fact, they expunge the very phenomena systems researchers are searching for in complexity and life. A formalism can be a model only of that aspect of nature (the external referent) that is similarly entailed. Mechanistic models can model mechanisms but nothing more. Nevertheless, most of the scientific community is engaged in using Turing computable formalisms to model nature without considering when it degenerates into a simulation with entirely different entailment structure.

A parallel situation exists on the contextual side. Models in social science, aside from their material components, tend to be qualitative, constructive, dialectical, participatory, subjective, experiential, and so forth. In both scientific and non-scientific fields, they can be based on constructive belief processes, such as reaching agreements that become reality, as in open-ended inquiries that identify patterns for theory development. They are not typically investigations into law-like nature because cognitive and social phenomena do not have the same reliance on conserved states and precise laws on those states (except perhaps for strong belief systems). Some dialectical philosophies argue against the use of any prior framework or absolute assumption, seeking to be unconstrained by dogma. Of course, statistics and probability theory have entered this picture to provide more quantitative precision, just as it has in the natural sciences for the opposite reason.

The discussion here considers both pragmatist and realist views in relation. Thus the only position that need be taken between these views is that neither should be considered exclusive, but rather as complements in a very fundamental relation in nature and humanity. Good system research depends on being aware of what kind of activity and aspect of the system the researcher is engaged in, and then applying appropriate methods and tests.

In the contextual domain, which is more open to dialectical methods, conditions are co-occurring, they do not have mutually exclusive *locality*. For example, we may want to know where to find fish. Aside from consulting a fisherman, an ecological niche model might be used to describe the potential for fish to exist in some adaptive character space. It can be a density distribution model generalized and interpreted as potentials in nonlocalized character space, that is, the adaptive niche for the fish. For that model to be actualized as a prediction of occurrence, we first need to know how the specific dimensions of the character space—temperature, rainfall, and other factors—are themselves actualized in space and time. Hence, we depend on the actualization first of those factors, and after that on many other factors not considered in the adaptation model, that may interact with actualizations dynamically; some that may be chance factors, physical barriers, harvesting pressure, even density dependence. The point is, potential and dynamics must be modeled separately, then related at sufficiently fine granularity. Considering the work involved, it is understandable that we might prefer the dialectical fisherman, or perhaps a statistician.

Nevertheless, the niche that we model serves to *attract* fish, but its actualization is subject to dynamics of fish and the environment that may provide spatial or temporal constraints. Only the complex combination of these two kinds of models can be in any sense predictive of actual occurrence. Even then, it will require multiple scenario runs to map out the range of possible outcomes.

The dynamical models may be legitimately mechanistic aside from contextual changes, which then need to be modeled separately as boundary conditions. Those conditions may be said to be attractive in the sense of providing adaptive spaces that can be filled. These are more like analogs to the distribution being modeled. They provide suitability for something "like" fish based on previous occupation. Analogy, that is, analogous potential, is thus the dominant paradigm of the contextual domain. The ecological niche for a fish is a potential for existence of a species that is analogous to such fish. The fact of existence of such potential landscapes means that otherwise unrestricted dynamical processes will tend to "fill the space," and in that sense it really does attract the dynamics of occupation while leaving actual occupation uncertain.[12] For example, good hunting grounds might set up migration patterns, but other events might still intervene.

We should now revisit the thorny distinction between theoretical models and simulations. Theoretical models are also whole systems with physical correlates (brain or computer states, drawings, etc.) and natural systems are whole with their implied laws or dispositions. Every context has an actualization and every actualization has a context. What we study is how these relations are organized and how they change, for example, how surrogacies are established. The modeling relation compares the entailments of related systems. It is not only about getting the inputs and outputs to match, which a sufficient simulation can also do. The modeling relation relates the way the domains work, testing a proposition or theory. In contrast, Rosen (1993) described simulation as a form of mimicry, where it is the behavior alone that is replicated, often by uncorrelated processes.

But this is a sticky issue in the philosophy of science. As a practical matter no model can be a perfect mirror of a natural system, according to relational theory itself. The critical difference between model and simulation involves three factors: belief, intent, and method. We believe something about how nature is entailed only through experiment and inference, so we cannot absolutely distinguish between a simulation and a model on the basis of performance. But we also know our intent: if we are attempting to discover nature's rules or not. What we might call a model

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[12] Note the subtle difference between this idea of a natural attractor and current computational meanings of the term attractor. The former is a tendency, whereas the latter is a description of actual behavior patterns.

today may indeed be considered only a simulation tomorrow, but there is still a big difference in making the attempt to find meaningful patterns in phenomena, incrementally improving our view. There is a difference in method. The model attempts to entail processes we have not yet seen; it tries to be predictive or at least capable of forecasting interesting information; making propositions and testing them. The well-known problems of reductionism resulted from too rigid a belief about underlying causes that remained unquestioned.

Simulations are thus rarely useful beyond the data they are built around. This argument can also apply to statistical models—validity depends on inferring the correct underlying natural distribution of the events represented by data. If so, statistical descriptions and probabilistic hypotheses are merely about simulations. Neither "goodness of fit" nor confidence intervals are valid if the researcher does not know the underlying distribution. For example, many studies assume the Gaussian Normal Distribution because a lot of statistical procedures have been developed for it. But if the actual distribution is not Gaussian Normal, using it is no better than guessing. A fit to behavior is not necessarily a fit to the pattern of that behavior, unless one experiments to discover the underlying distribution.

So, these problems would seem to apply to any practical computer-based implementation of the relational framework as well. Yet, there is a difference in how the algorithmic model is constructed; if it entails some natural property one can reasonably expect to characterize the phenomena (like a valid underlying statistical distribution). In that case better model approximations are possible and they can converge on their own kind of natural referent. Therein lies the difference, a mechanistic model will converge on a mechanism no matter how it is constructed. Relational modeling will converge on whole systems or whole sub-systems. A crude analogy is that one can take a car apart mechanistically and if reassembled properly, it will again be a car. But if you do that with a cat, you won't end up with a cat. However, we have learned how to do cellular replacements and whole organ transplants, thus how to decompose and recompose a complex system in terms of wholes.

Thus, while mechanistic formalisms can indeed model dynamics within a stable context, and other methods can model the suitability landscape, neither are models of species occurrence and niche occupation without a relational model that says how context and dynamics inform each other in a given case.

Concluding Remarks

These very general comments on the nature of holistic modeling would remain somewhat vacuous if systems researchers do not apply them to develop better models of complex systems. Hopefully it became clear in the previous discussion, there is no need to revise the foundation of mechanistic models as applied to simple mechanical systems for which they are appropriately designed. Furthermore, the use of mechanistic models remains as a component of complex system modeling, where "complex" means having complementarities. However, the need in modeling complex systems is for something more that will, in a loose sense, "fill in the space" between mechanisms and give them contextual meaning (which they cannot represent). Thus complex system modeling involves identifying the *semantic residue* that remains in any syntactic representation.

That semantic aspect is like a mirror reality, as in the concept of a co-space. For example, different topologies can be related by a mathematical transformation. In this case neither the object space nor its mirror-like co-space can be said to contain "the thing itself," which exists as a relation between them; or in any case requires both for its description. That relation, however, is cognized directly by the mathematician during encoding and decoding. Mathematics exists in that relational space, as do classical laws and other constructs like Platonic forms; but we work with the tangible objects that are encoded or decoded. A great deal of modeling goes on within mathematics itself, as attempts to develop syntax for logical objects. Then if mathematics applies to nature, so does modeling itself.

The epistemology of this view has been discussed in Chapter 2, listing six criteria that it meets for a valid and necessary worldview. Yet, it is not the only possible approach. How systems researchers go about modeling complex systems is necessarily a discussion of which approach might be a *better* description of nature, or alternatively, which personal interactions with a system we should consider most valid. Ultimately, we cannot abandon some form of natural realism in which we seek to improve knowledge, whether it involves attributing reality or inheriting it.

Rosen (1993) recognized that scientific modeling is a constructive process that humans do, but he also described its presence in nature; that organisms, at least, are characterized by the fact that they build and use internal models. The realist interpretation would then conclude that nature *does* modeling. The pragmatist would instead say that modeling remains in the human domain, and is about our projection onto nature. It is obvious that the realist interpretation of something equivalent to mind in nature (a claim made by Gregory Bateson, 1972) was unpopular and even professionally dangerous in Rosen's time. But Rosen was a realist at heart and he gave many hints about the mind-body relation being much more general than commonly believed.

The developments described here are consistent with that view, that *mind* in people and *mind* in nature are the same in principle, but different in evolutionary development. It is indeed a problem to suppose the existence of experiences that are not ours, but once again we must appeal to parsimony, in this case not to suppose they are different. While at one level this assumption may contradict a strictly Newtonian world, Newton's general philosophy was not restricted to mechanisms, even though he described them. In fact, we can fall back on Newton's own view of parsimony: "We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances. Therefore, to the same natural effects we must, as far as possible, assign the same causes" (Newton & Machin, 1729, p. 384).

But given the tremendous community pressure, especially in the West, to "arrogate mind to ourselves" (Bateson, 1972, p. 468), the mainstream relational view (if one can call it that) initially presents complexity counter-positively from the impossibility of mechanistic closure. Rosen demonstrated that mechanisms without some intervening semantic quality cannot exist even mathematically in the domain in which they are defined. He demonstrated this most rigorously, following the lead of Albert Einstein (1879–1955), by establishing an iron-clad paradox to be resolved by his followers (see Chapter 2). That paradox consisted of two established but incompatible facts: (a) that closed efficient entailments characterize life, and that (b) they cannot exist in a purely mechanistic context. Resolving this paradox requires us to shift perspectives from the view that complexity *emerges* from a syntactic world, to the more parsimonious view that syntax and semantics belong to a complex world.

If we ask what is happening within the contextual world, with final and formal cause, we see that the laws themselves are of a different character than for actual phenomena. Contextual interactions are inclusive (i.e., co-occurring), such as the Venn diagrams, not mutually exclusive like measurable events or physical objects. Philosophers debate the status of properties of objects, which seem more to belong in the world of context (Lowe, 2006). Even the arithmetic in the contextual domain is different than in the discrete world where we can write the exact entailment, that $1+1=2$. In co-occurring spaces, one system plus one system can be 0, 1, or 3 systems. That is, it is not possible to know of two contexts without a third by which they are known. There are also two ways to get the third system, by reduction or by emergence. The former increases constraints, the later decreases them, thus allowing new systems and properties context for existence.

There are many things relational modeling can do. As mentioned in Chapter 2, what it can and cannot do is one of the six epistemological criteria for evaluating it ("fruitfulness"), but that is a test of time and application. It would be pointless to list the possibilities. However, it may be useful for readers to have a few starting points to try it out. The most obvious one is to re-organize the plethora of conceptual maps in existence by assigning the framework labels to boxes and arrows and experimenting with implicit organization. It is virtually certain to be an informative exercise that will not only improve knowledge about the system, but will also help to advance relational theory. Perhaps another most immediate opportunity is to develop adaptive niche modeling as a general modeling approach within this framework. Its applications should extend far beyond biology. A third recommendation, and perhaps the strongest of all, is that the relational framework very strongly implies a new kind of informatics that is capable of integrating syntax (quantitative dynamics) and semantics (qualitative context). The resources and effort to explore that development is our strongest recommendation.

Meanwhile, of course, we will explore how direct application of the framework itself, for example in Participatory Action Research and other similar procedures, can bring considerable natural order to one's understanding of a complex system; suggesting more complete descriptions and more penetrating analysis of subsystems, intervention points, systems organization types, emergence possibilities, general tendencies and/or suitabilities for phenomena, and so forth. Chapter 5 takes us to the state-of-the-art in applying systemic reasoning to complex systems questions using various methods within the general framework and sets the stage for new forms of modeling.

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Chapter 5
Taking Action Using Systems Research

Shankar Sankaran

Abstract The aim of this chapter is to guide you to conduct your systems research project. It will start suggesting some ways to establish a research project based on traditional project management principles and compare it with ways in which a systems researcher might set a research project. It will then explain the importance of constructing a methodology for your research project and point out why systems researchers often adopt multimethodologies to carry out research. The chapter will then focus on how systems interventions can be developed to contribute to your research methodology with examples of multimethodology and systemic action research interventions that have been successfully used by prominent systems researchers in different contexts. The chapter will then take you through some steps normally used in conducting a research project, with an emphasis on systems research, covering an overview of research methods, negotiating relationships to get access to research sites, data collection and analysis methods, and ways to demonstrate rigor. Since this chapter covers a wide area, bridging systems interventions to ways in which conventional research is carried out, it will focus more on how systems interventions can be set up and implemented and provide a variety of references to help the reader find adequate information to carry out research expected of doctoral studies or research reports. It will also make reference to other chapters in the book to guide the readers to take effective action to complete a research project successfully.

Keywords Action research • Multimethodology • Systemic intervention • Research methodology • Research methods • Research project management

> When someone is asked how he would behave under certain circumstances, the answer he usually gives is his espoused theory of action for that situation. This is the theory of action to which he gives allegiance, and which, upon request, he communicates to others. However, the theory that actually governs his actions is this theory-in-use.
>
> (Argyris & Schön, 1974, pp. 6–7)

The previous four chapters of this book have introduced you to Philosophical Foundations of Systems Research, the role of Frameworks in conducting Systems

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M.C. Edson et al. (eds.), *A Guide to Systems Research*, Translational Systems Sciences 10, DOI 10.1007/978-981-10-0263-2_5

Research, Problem Structuring and Research Design, the use of Models and, specifically, Models in Systems Research. In this chapter, the focus is on Taking Action to carry out the research to answer your inquiry's central research question or concern. The main question being addressed in this chapter is, "How is Systems Research actually carried out in a systemic (holistic, comprehensive investigation), as well as systematic (logical process and procedure) way?" For scholars wishing to carry out *systems research*, this question poses an additional challenge as they attempt to carry out research respecting the traditions of research in their own fields while at the same time carrying out their study systemically.

Once you have identified your research question(s) and are ready to start your research, there are a few choices to consider:

- Should I set up my research using a standard project management methodology to treat this as a "research" project?
- Should I use recommended methods adopted in doctoral research programs?
- Are there any frameworks that are more suitable to set up systems research?

These are some questions that will be discussed in this chapter.

There are many good books that are available to help you with details of research methodologies and methods that you can use to set up and carry out research. However, this chapter will not cover those topics but mention them and direct you to books for more information that you may find in your libraries or bookshops.

Getting Started

There are a few paths that a researcher can take in setting up a research project once the research questions or concern is established. The traditional view of setting up a research project is to carry out a literature review and find a gap to address that can help to contribute new knowledge to the field. As famous systems researchers Churchman, Ackoff, and Arnoff (1957) stated, "There is an old saying that a problem well put is half solved. This much is obvious. What is not so obvious is how to put the problem well" (p. 67). This is why Chapter 3 provided you with some ideas to structure your research problem using some ideas from systems practice. We will look at three choices to proceed—a project management approach, a dissertation approach, and the framework, methodology, and action (or FMA) approach proposed by Checkland (1985) with some improvements suggested by Ison (2010).

A Project Management Approach

Working on a research project is, in many ways, similar to working on conventional projects that deliver products or services. The Project Management Institute (PMI) publishes *A Guide to the Project Management Body of Knowledge or PMBOK* (2013) according to which "A project is a temporary endeavor undertaken to create a unique product, service or result. The temporary nature of projects indicates that a project has a definite beginning and an end" (p. 3). This broad definition also applies to a research project.

The International Council on Systems Engineering (INCOSE) provides guidelines to practitioners who manage systems projects. INCOSE (n.d.) defines a system as a "construct or collection of different elements that together produce results not obtainable by the elements alone" (What is Systems Engineering, para. 4) and systems engineering as an "interdisciplinary approach and means to enable the realization of successful systems" (What is Systems Engineering, para. 1).

Systems research often tends to transcend boundaries between interconnected disciplines to enable a holistic view. Hence, a systems engineering approach could help in setting up a research project.

Both project management and systems engineering define a life cycle through which a product or service is delivered. Systems engineering recommends early engagement with stakeholders that one would use in conventional research due to ethical approvals required to start the research. A typical project management life cycle goes through the phases of *initiating, planning,* managing the plan actively (by *executing, monitoring,* and *controlling* the project) and, finally, handing over the results of the project to its beneficiaries, and *closing* the project.

Traditional project management works well when you can clearly define the goals and methods at the start. However, projects often exhibit uncertainty and ambiguity and do not deliver the intended benefits. Agile project management grew out of these concerns and is frequently used to deliver (information) systems projects where the project is carried out iteratively to ensure that it delivers timely and beneficial outcomes.

Agile project management is defined as "an alternative to traditional project management, typically used in software development. It helps teams respond to unpredictability through incremental, iterative work cadences, known as sprints. Agile methodologies are an alternative to waterfall, or traditional sequential development" (Agile Methodology, 2008, "What is Agile," para. 1). Research projects often exhibit the characteristics of projects that are to be managed using an agile methodology. There have been other alternative methods to overcome the weaknesses of the waterfall model (due to which agile project management became popular) such as the Vee and Dual Vee models (Mooz & Forsberg, 2001).

Wysocki (2013) has written a book that covers traditional and agile project management. For more information on systems engineering see INCOSE (2015) and Kossiakoff and Sweet (2003).

Are research and development projects managed in different ways? Wingate (2015) confirms that they are and discusses a flexible approach to managing research and development projects. He emphasizes the importance of a "methodical, cyclical and iterative approach to reach a succession of uniquely defined targets or outcomes" (p. 17) that uses a mixture of conventional and agile approaches to managing projects. According to Wingate, this approach requires:

- The interpretation of user stories that define functionality;
- Close collaboration with a customer;
- Phased development and user-involved testing;
- The formalization of a budget and schedule; and

- Active management of the plan, including change management, risk management, performance measurements and communications. (p. 17)

Overall, it is good to keep useful project management principles in mind while setting up your project.

A Dissertation Approach

A typical research project also involves a life cycle that is replicated in the way research reports, dissertations, or theses are written and submitted. More will be said about writing in Chapter 6. A research report usually starts with a *background* to the research (what prompted this research including a description of the environment where the research is carried out); a *literature review* (to identify previous knowledge that exists in the area of research, often ending with a gap that justifies the current research); justification of the *methodology* or methods adopted including a discussion on validity and reliability; describing the *data collected*; showing how the *data is analyzed* and ending with *discussions* about the findings leading to the project's *conclusions* and *recommendations*. It is also customary to list down the limitations of the research, explain the contributions from the research to theory, practice and policy (if applicable) and point to future directions for the research.

Several books explain how to conduct a doctoral research study (Evans, Gruba, & Zobel, 2014; Perry, 2013; Phillips & Pugh, 2010). Often these books help by suggesting a number of essential chapters (usually five or six for a conventional dissertation or thesis) and describing what is expected in each of the chapters. This could be another way to set up your research by using a suggested table of contents provided in these books.

Did your university or institution or a client organization provide you with requirements on how a doctoral dissertation (or thesis) or a research report is to be structured for submission? You could use that to set up your research.

Chapter 6 of this book will provide more guidance on writing up your dissertation or thesis that can help you plan and structure your research journey as well.

A Systems Research Model

In Chapter 6, Varey explains why a linear dissertation approach may not suit writing about systems research. The reasons provided are similar to the differences between a conventional, linear project management approach and a recursive, agile project management approach. Metcalf (one of the authors of Chapter 8 of this book) advocates an approach to carry out systems research that can be useful as a model for systems researchers (Metcalf, 2016). It is based on the systemic action research concept (discussed later in this chapter). Figure 5.1 illustrates the 7-step approach advocated by Metcalf, and Table 5.1 breaks down these seven steps further. You will find a detailed explanation of how this model is applied in practice in Chapter 8.

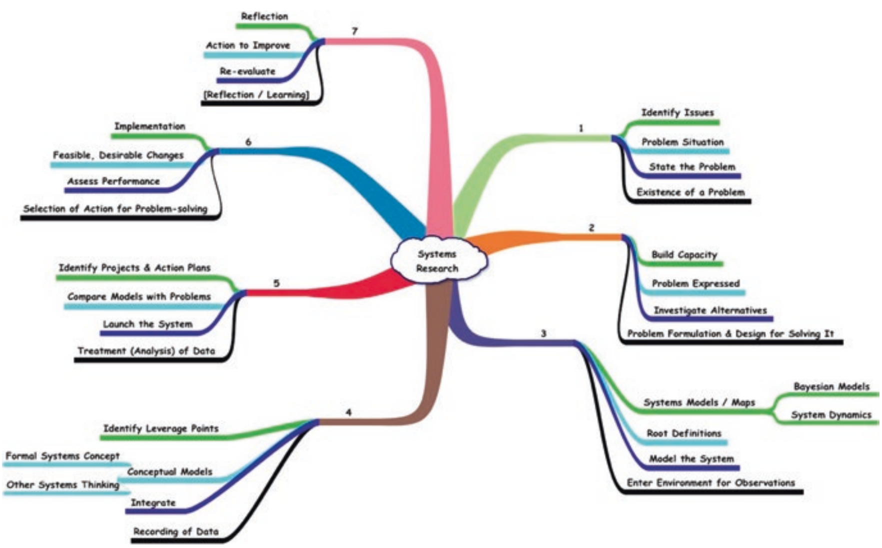

Fig. 5.1 Systems research model (Metcalf, 2016, reproduced with permission). Combining four versions of action research, in order from top to bottom of each branch (Incorporating Evolutionary Learning Labs, Soft Systems Methodology, SIMILAR, and Ackoff, 1953)

Table 5.1 A systems research model (based on Metcalf, 2016)

Systems research	
Steps	*Activity*
1	Identity the topic, or system of interest, for your study.
A	Identify the issues for the study
B	Identify a problem situation to be explored
C	State the nature of the problem to be studied
D	Identify the existence of a problem
2	Clarify your beginning points. What capacity do you or the community involved have for creating change? What is the problem that needs to be resolved? What specific question will you use as the basis for your study?
A	Build capacity (e.g. the PAR team of co-researchers)
B	Express the problem in question
C	Investigate alternatives to address the stated problem
D	Formulate both the problem and potential design for solving it
3	What do you know thus far about the system that you wish to change, or to better understand? How clearly can you model describe the phenomena involved?
A	Construct systems models/maps (using Bayesian Models/System Dynamics Models)
B	Create root definitions
C	Construct an initial model of the system
D	Enter the system environment as the observer, to gather data

(continued)

Table 5.1 (continued)

Systems research	
Steps	*Activity*
4	Choose the best points of potential intervention in the system that you wish to change. How clearly can you describe, so far, the system as it exists (or the system that you wish to design)? How well do you understand the system in question??
A	Identify leverage points
B	Conceptual models (Formal systems concept/Other types of systems thinking)
C	Integrate the model of the system that was developed
D	Record data that were gathered
5	As you interact with the system in question, what are you learning? If your goal is to intervene in the system, what resistance or reactions are you encountering? As you compare your models with the realities of the system, how closely are they aligned? As you gather data for research, does anything surprise you?
A	Identify projects and action plans
B	Compare conceptual models with actual problems
C	Launch (try out) the system that was developed
D	Analyze data that were gathered
6	Now that you put your plan into action, what effect has it had? Or if you have been gathering research data, what do you now know about your system of interest?
A	Implement changes based on the leverage points identified
B	Determine the changes which are feasible and desirable
C	Assess the performance of the model as tested
D	Select the action to be taken to solve the problem in question
7	As you think through the process that you have completed, how well did it work? What have you learned, and what needs to be learned next? What issues or problems now need to be addressed, or how has the system of interest changed?
A	Reflect on the process and outcomes
B	Take action to implement feasible and desirable changes
C	Re-evaluate the quality of the solution model
D	Evaluate and summarize outcomes

The FMA Model

Peter Checkland and his associates propose a model for carrying out research that is often adopted by systems researchers.

Checkland (1985) stated that in order to link our ideas to actions it would be good to distinguish between the basic sets of ideas and the process we use to take action in an organized way. He suggests following a systematic way for “rational intervention” in human affairs to link theory and practice, which is often referred to as the FMA model.

In this model “F” stands for a “Framework of Ideas,” which refers to the collection of ideas or theory that forms the basis of our personal understanding of the world. It acts as a perspective or lens through which we look at the world and make sense of it.

Our understanding of the world then enables us to make decisions about how to act. It is sensible for our actions to be consistent with our perspectives and so the model shows how the Framework of Ideas informs the method of action, or the "Methodology," M.

Our methodology of putting our understanding into practice is then applied to a particular problem situation, or what Checkland calls "A," the Area of Application in which we carry out an intervention.

Checkland (1985) summarizes this by stating that the FMA model includes

> a framework F, a way of applying these ideas in the methodology M, and an application area A. A is indicated without sharp boundaries to remind us that when A is human affairs, the application of F, through M, may lead us into byways not initially expected. Having used M, then, we may hope for, and may reflect upon what learning has been acquired, learning about all three elements: F, M and A. (p. 758)

Figure 5.2 shows the adaptation of an FMA model using some ideas of systems you are familiar with from the previous chapters of this book.

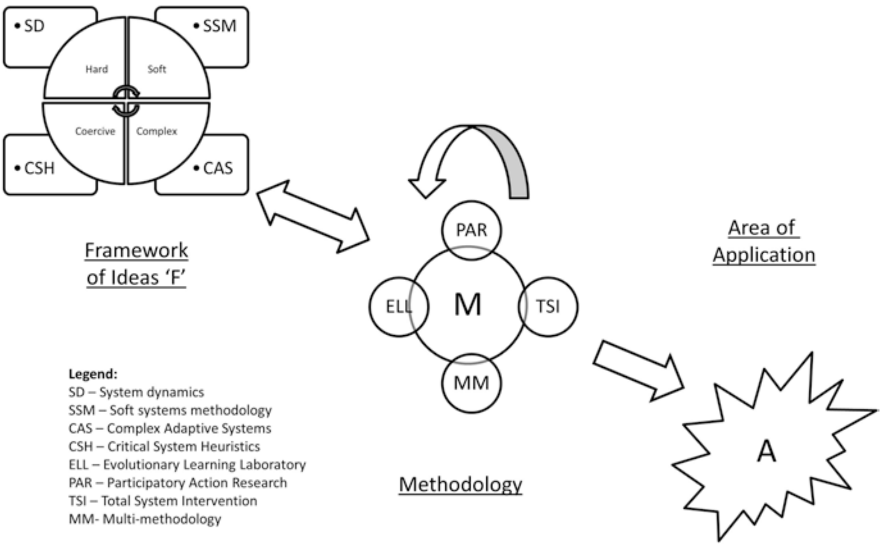

Fig. 5.2 FMA model

Ison (2010, p. 48), observing the importance of researchers' reflexivity, proposes the acronym PFMS for a model for conducting research where P stands for practitioner, F for framework of ideas, M for method, and S for the situation. Ison explains that "the generic description of practice comprises of a practitioner (P) with a history, a tradition of understanding, possibly a chosen framework of ideas (F) a chosen method (M) and a situation (S) in which they practise" (p. 49) to carry out an intervention. He derived this acronym informed by practice after starting his intervention with Checkland's (1985) FMA model.

A group of students at Monash University in Australia who used systems intervention processes in a doctoral program for several years have successfully used Checkland's FMA model to set up their doctoral research projects (Sarah et al., 2002).

Suggestion

- Whatever path you follow, remember the Terry Pratchett (2010) quote:

  > If you do not know where you come from, then you don't know where you are, and if you don't know where you are, then you don't know where you're going. And if you don't know where you're going, you're probably going wrong. (p. 223)

- So it is important that you should do the legwork to get to the point when you are ready to embark on your research journey. Even if you do not follow any project management method it is good to have some timelines or goals that you can establish at the start of your journey to be able to review them regularly and take some remedial measures if you are not reaching them. One advice I always give my doctoral students is to start writing early. Writing is a form of thinking. Do not put it off. I am sure you will get more practical advice on that in Chapter 6.

Questions you may want to ask yourself at this stage:

- What process am I comfortable with to carry out my research?
- Is the process systemic as well as systematic?
- Is it beneficial to use standard or systematic processes?
- Or is it better to be more flexible in my approach?

Methodology

It is important to distinguish between the terms *methodology* and *methods* before you start your research as they are often used interchangeably; however, they serve different purposes. We will explain the use of methodologies with reference to systems research in this section and look at methods later in this chapter.

Methods are "actual techniques or procedures used to gather and analyze data… [while methodology] is an analysis of how research should or does proceed" (Blaikie, 1993, p. 7). In most disciplines, researchers tend to use one methodology (from one paradigm) but it is quite common for systems researchers to mix methodologies. Even in other fields the use of mixed methods is becoming more common and acceptable. In essence, multimethodology promotes the use of more than one methodology irrespective of which paradigm the methodology belongs to. You can find more information on systems researchers' use of multimethodologies from Mingers and Brocklesby (1997, p. 7), Midgley (2000, Chapter 9), Midgley (2011), and Bowers (2011). It is always good to layout the research methodology while conducting systems research.

Systemic Intervention Processes

Systems researchers often construct their methodologies systematically to carry out systemic interventions. Let us look at a few examples in this section. First, we will start with some definitions.

Midgley (2000) defines an intervention as "*purposeful action by a human agent to create change*" (p. 113) and "*systemic* intervention is purposeful action by an agent to create change in *relation to reflection on boundaries*" (p. 129). Midgley, Munlo, and Brown (1998) propose a theory of *boundary critique* which requires systems researchers to be aware of boundaries they set themselves while carrying out a systemic intervention. According to Midgley et al. (1998), Churchman (1970) was the first systems thinker to point out that boundary analysis is critical. While Churchman (1970) argued for "sweeping in" as much information as possible to decide on the boundaries, Ulrich (1996) proposed that boundaries need to be set using a rationalistic approach based on the Critical Heuristics Systems Approach. Midgley et al. (1998) extended the work done by Churchman (1970) and Ulrich (1996), but suggested that there could be conflicts between groups of people who may differ in ethical perspectives of the situation which may result in different boundaries. He argued that sometimes it may be necessary to seek input of people who are not directly involved or affected by the intervention and may be able to bring useful perspectives on how to decide on the boundaries of the intervention. It will be useful to read more about boundary critique from Midgley et al. (1998). I would also recommend looking at the 12 critically heuristic boundary questions suggested by Ulrich (1996).

Midgley (2000) further argued that even scientific observation, where the observer designs his and her research not to influence the observed, "*has to be seen as a form of intervention* [as] Observation is undertaken *purposefully,* by an agent, to *create change* (in knowledge or practice)" (p. 128). We will discuss six interventions used by systems researchers—Action Research (AR/PAR), Systemic Action Research (SAR), Evolutionary Learning Laboratory (ELL), Total Systems Intervention (TSI), Practical Intervention (using multimethodology), and Soft Systems Methodology (SSM).

Action Research

Action research is a cyclical process that can be configured to carry out a systemic intervention. Essentially, action research is a cyclical-spiral process that

> pursues both action (change) and research (understanding) outcomes. It achieves change through a participatory approach, often in conjunction with other change processes. The research is achieved by being responsive to the situation and by searching strenuously for disconfirming evidence. At the heart of AR is a cycle that alternates action and critical reflection. (Dick, 2001, p. 21)

Often action research is carried out in a 4-stage cycle of Plan-Act-Observe-Reflect and the outcomes of one cycle feed into the planning of the next cycle. Action research can use a variety of methods as it is data-driven.

Action research is not a single method or methodology, but refers to a variety of approaches that involves working collaboratively with people who are facing a concern that needs some deliberate action to be taken to address it. Such collaboration creates buy-in for implementing the change that accompanies the action. The group of people who are working together with the action researcher are treated as co-researchers rather than informants. Action research is a cyclic process alternating between action and reflection upon the action to initiate further action converging towards improving the situation of concern (Sankaran & Dick, 2015, pp. 211–212).

Hagmann, Chuma, Murwira, Connolly, and Fiarcelli (2002) reported on the use of a participatory action research study in integrated natural resource management in Zimbabwe. This study reported how the researchers developed appropriate solutions together with the farmers, which empowered them. The cyclical process used by Hagmann et al. (2002) is shown in Fig. 5.3.

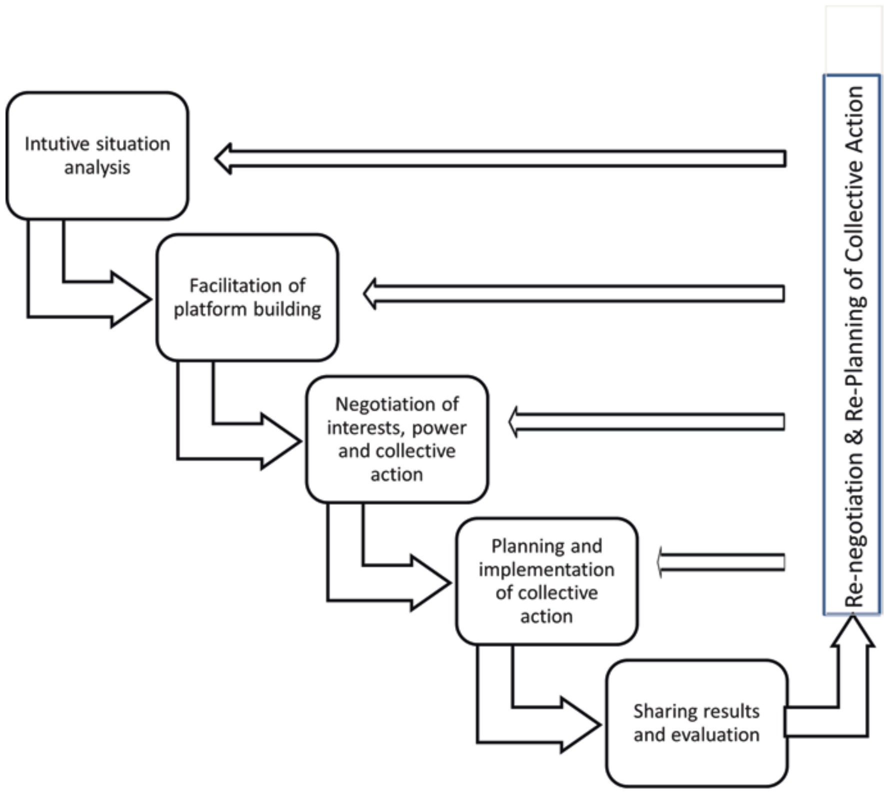

Fig. 5.3 Example of a project using PAR (Adapted from Bosch & Nguyen, 2015, p. 19)

Some good books to read about applying action research are Stringer (2013), Greenwood and Levin (2007), and Selener (1997).

Systemic Action Research (SAR)

Some systems researchers working in community development, international systems development, and with natural systems believe that the conventional 2-step "action-research" or the 4-step "plan-act-observe-reflect" are not comprehensive enough to carry out a systemic intervention. Some of these enhancements are discussed in this section.

Wadsworth (2010, p. 71) suggests an 8-step cycle, or moments, in her work on living systems inquiry evolving from a simple two moment cycle alternating between action and research, to a four moment cycle of action-observe-reflect-plan expanding to an eight moment cycle of

1. Old action
2. Observe
3. Values
4. Reflect
5. Theorize
6. Conclude
7. Implement-plan, and
8. New action.

Ison (2010), elaborating on the difference between action research and systemic action research, observes that "within systemic action research the 'researcher' understands and acts with awareness that they are part of the researching system of interest under co-construction, rather than external to it" (p. 274). He also quotes Burns (2007) who suggests that "systemic action research offers a 'learning architecture' for change processes that draw on in-depth inquiry, multi-stakeholder analysis, experimental action and experiential learning" (p. 1).

Ison (2010) then proposes a 4-stage model for systemic action research grounded in a second-order cybernetic understanding. He considers conventional research to be first-order.

- Stage 1: Bringing the system interest into existence (i.e., naming the system of interest)
- Stage 2: Evaluating the effectiveness of the system of interest as a vehicle to elicit useful understanding (and acceptance) of the social and cultural context
- Stage 3: Generation of a joint decision-making process (a "problem determined system of interest") involving all key stakeholders
- Stage 4: Evaluating the effectiveness of the decisions made (i.e., how has the action taken be judged by the stakeholders? (p. 275)

The elaboration of the conventional 4-stage cycle to a more elaborate explanation of the steps has been derived by Ison and his co-researchers through their work on agricultural systems.

Professor Richard Bawden and his colleagues at the Hawkesbury Agricultural College in Australia developed an action research model that incorporates systems thinking based on action research (Bawden, Macadam, Packham, & Valentine, 1984).

Table 5.2 (extracted from Bawden et al., 1984, pp. 211–212) shows how the Hawkesbury researchers have differentiated between reductionist and systems approaches. While they found soft-systems approaches to be useful, they suggest that all four methods can be used depending on the problem to be resolved.

Table 5.2 Approaches to problem-solving (based on Bawden et al., 1984)

Reductionist scientific approach	Reductionist technological approach	Hard systems approach		Soft systems approach
Problem situation perceived				
Problem defined				Problem situation expressed
Problem reduced		Relevant descriptive systems identified (using systems concepts)		Relevant transforming systems identified (using systems concepts)
Explanation hypothesized	Alternative solutions generated (taking scientific explanations into account)	Optimizing models designed (taking into account scientific explanations and technological solutions)		Transforming system modelled (using systems concepts)
Hypothesis experimentally tested	Alternative solutions evaluated	Splits into one of two directions based (taking into account systems concepts)		Models compared with reality (using systems concepts)
Reduced problem explained	Optimizing solution selected	Alternative solutions evaluated	New system built	Desirable and feasible changes debated (using both scientific explanations and hard systems methodologies)
End	Solution action implemented	Optimizing solution selected	New system tested	Changes in Structure, Procedure, Attitude
	Action validated	Action implemented	Systems validated	Outcomes validated
	Problem (as reduced) solved	Action validated	End	Problem situation improved
	End	System problem solved		Usually recycles
		End		
Output—This is why statement	Focus is on what is to be done and not what is? Why is it so?	Less useful when goals or purposes of the system are vague and nonquantifiable		Found most useful in tackling real-world problems in the context of the Hawkesbury programs

Burns (2014, p. 4) argues that while many action researchers have extended the reach of action research their work does not deal with systemic properties of the issues that arise in problems that exhibit vicious cycles, multi-directional causality, nonlinear change that cannot be attributed to individual intervention. These are the types of problems that systems researchers often encounter while intervening in a situation. Burns (2014, p. 4) provided the comparison shown in Table 5.3 to differentiate between forms of action research and systemic action research.

Table 5.3 Comparison between the focus of various forms of action research and systemic action research (based on Burns, 2014, p. 4)

Forms of action research	Systemic action research
Reflective practice	Individual reflect on their own practice
Action learning, action science, and action inquiry	Group processes to support individual reflection
Co-operative inquiry	Group reflection on group endeavor
Participatory action research	Community-based generation of knowledge for community action
Systemic action research	System wide-learning

Burns (2014) lists the key characteristics of systemic action research as:

- Focus: Action which change the system dynamic
- Design: Multiple inquiries connected horizontally and vertically
- Membership: Dynamic—following the issues
- Significance: Resonance and resonance testing (p. 7)

He points out that while power relationships have to be explored in action research, engaging with power has implication on how systemic action research is conducted which can sometimes challenge the participatory nature of action research.

The point Burns (2014) makes about significance is important on what we learn. He states that “resonance allows us to determine what is important, and where the energy for change lies within the system” (p. 12). He uses resonance in two ways:

- Identifying energy and points of connection between people in the system where we are intervening
- Testing the legitimacy of the issues by taking stories from one area to another. This leads to better engagement and ownership

From the various views on how action research should be configured to render it to be systemic, it is obvious that systems researchers have to think deeply and build their own models of systemic intervention which would be appropriate in the context where they are carrying out their research.

What is the implication of these discussions for this chapter on taking action? Ison (2010) lists the following features that distinguish systemic ways of taking action from systematic ways:

- A systemic researcher is a participant-conceptualizer and how he/she perceives the situation becomes critical in systemic research.
- Places more responsibility on the ethics of intervention as what may be good for one situation may not suit another (more on ethics in Chapter 6).
- The main focus of exploration and change is based on how the system of interest is specified and how this system interacts with its context.
- Experience plays an important part in identifying patterns by being sensitive to meaning generated by viewing events in their contexts.
- From time to time, it is important to stand back to understand the systems in which the practitioner is immersed. (p. 193)

Evolutionary Learning Laboratory (ELL)

Bosch, Nguyen, Maeno, and Yasui (2013) developed the concept of Evolutionary Learning Laboratory (ELL) to manage complex issues. They proposed using a 7-step cycle to a conduct a systemic intervention. Figure 5.4 shows the process.

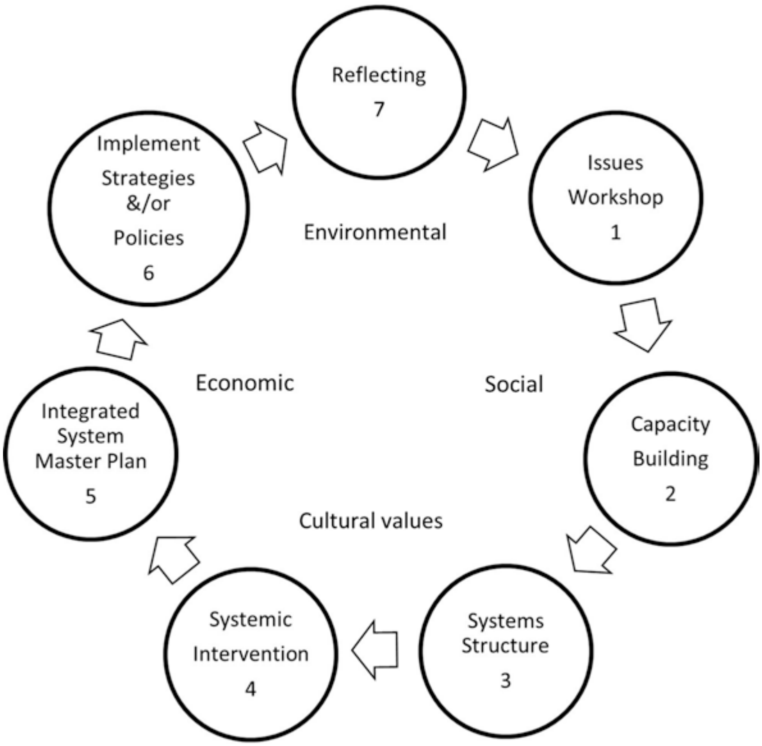

Fig. 5.4 Evolutionary learning laboratory

The ELL process starts with Step 1 by conducting an "issues workshop" in a series of forums to gather and evaluate the mental models of stakeholders involved in an intervention. This feeds into Step 2, called capacity building, where the stakeholders integrate the various mental models captured in Step 1 to systems structures creating a model. Software tools are used to assist in developing this model. The stakeholders then interpret and explore the model from a systems view, observing all the interactions (loops) to understand their interdependencies. This greatly helps to develop a shared understanding of the problem (or issues) being addressed in Step 3. This shared understanding leads to the development of a systemic intervention in Step 4 by identifying leverage points that can lead to effective change. Once this is identified, a master plan is developed in Step 5 that includes goals and strategies. ELL uses Bayesian Belief Network (BBN) modelling (Smith, Felderhof, & Bosch, 2007) to help in the development of the master plan. Step 6 is essentially taking action based on the master plan to implement strategies and/or policies followed by Step 7, which involves reflecting regularly on the outcomes and actions to look for unintended consequences or to eliminate barriers to implementation.

The ELL methodology has been successfully applied in a variety of applications. A good book to start understanding how ELL can be used as a systems intervention is by Bosch and Nguyen (2015).

Total Systems Intervention (TSI)

Total Systems Intervention or TSI (Flood, 1995) is an approach to problem solving that combines a set of methodologies/methods based on the principles of systems thinking. It was founded on the theoretical principles of Critical Systems Thinking (Flood & Jackson, 1991). Designing a TSI starts with a philosophy that takes a systemic view. TSI asks the interventionist to use two key principles:

1. Consider the relationship between different interests within an organization looking for dominance that could prevent participation, and
2. Reflect on the dominance of approaches that are favored to cause an intervention.

The process of setting up a TSI includes three phases (Flood & Jackson, 1991):

1. Creativity—Helps to surface issues to be dealt with,
2. Choice—Choose a method to manage the issues that are discovered at the creativity phase, and
3. Implementation—Use the methods chosen in the choice phase to manage the issues that emerged at the creativity phase.

Jackson (2003, p. 289) explains how TSI was used within the North Yorkshire Police in the United Kingdom to develop a strategy to achieve its mission. After gathering opinions from a wide group of stakeholders, a set of metaphors (G. Morgan, 1986) were used to describe the organization. A Viable Systems Model (VSM;

Beer, 1984) was used to interpret the organization from a “brain” perspective. An analysis of the Systems of Systems Methodologies framework led to the use of Ackoff’s (1999) Interactive Planning method as a process to develop a strategy for the organization. The method helped develop an idealized design for the organization. The idealized design was then presented in a 2-day workshop to the clients. Several problems arose that had to be resolved, but the overall intervention was successful.

Practical Intervention Using Multimethodology

John Mingers (2006) proposes a framework of three systems based on Habermas’s (1984, 1987) three worlds—material, personal, and social—to construct a systemic intervention using multimethodologies.

Figure 5.5 shows Mingers’ concept of an intervention.

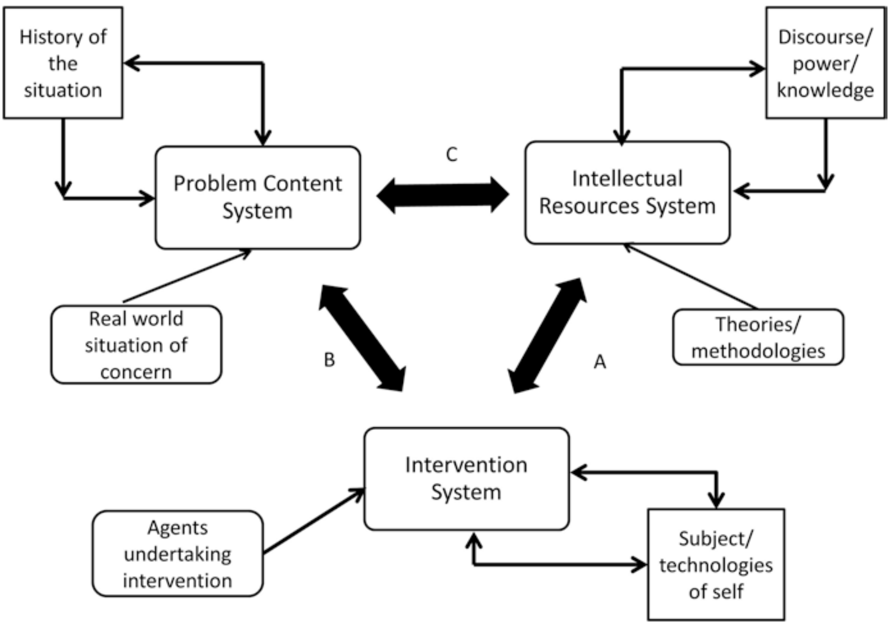

Fig. 5.5 Practical intervention (From Mingers, 2006, p. 217)

The intervention system comprises of people who are trying to engage with the problem content system. They may also be part of the problem content system. The intellectual resource system is the knowledge and competencies required (see also Chapter 7), such as, theories and methodologies that are useful to intervene in the problem situation. The three systems and the relationships between them shown by the arrows form the context for the systems intervention. Mingers (2006) provides a set of questions that can be useful in exploring the systems. He also suggests that the intervention has to take into account the material, personal, and social worlds (Habermas, 1984; 1987) in which the problem context is situated. He suggests a four phase approach to the intervention comprised of *appreciation, analysis, assessment*, and *action*, which is similar to other intervention stages discussed in this chapter.

Suggestion

Here are some questions from Mingers (2006, p. 219) that will be useful if you want to consider his proposed intervention. Please refer to his book chapter for the full range of questions:

- What has initiated your engagement?
- What skills do I possess in methods that will be useful for the intervention? How are values embedded in the methods useful for this situation? Will they be a hindrance?
- What commitment do you have to actors in the situation?
- Who do you see as customers, victims affected, and owners of the problem?
- What resources and power or influence that you have?

Soft Systems Methodology (SSM)

Soft Systems Methodology (SSM) evolved as an action research project by Peter Checkland and his associates from Lancaster University in the United Kingdom in the 1970s when they found that messy problems faced by managers cannot be resolved by normative methods like systems engineering. SSM (Checkland & Poulter, 2006) has also evolved from its original 7-step model that is often used for teaching to a more mature model that deals with sociocultural, power, and political issues that arise whenever we decide to intervene in a *problematical* situation to take action for improvement and learning more about the situation.

Figure 5.6 shows the steps of SSM as it has evolved today after being used first by consultants and then by practitioners themselves.

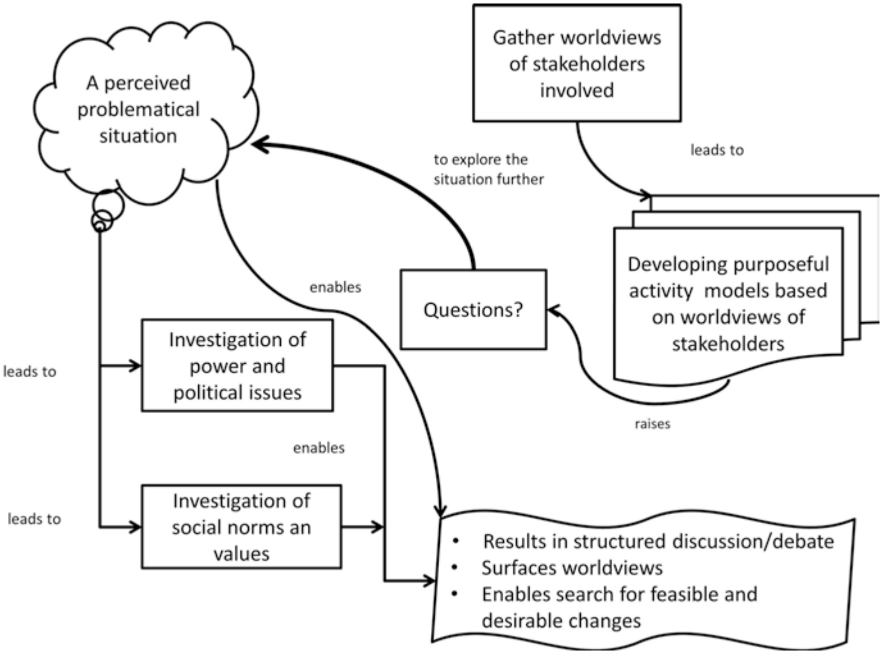

Fig. 5.6 Basic soft systems methodology (Adapted from Checkland & Poulter, 2006, p. 12)

Checkland and Poulter (2010) bring out the essence of the SSM process by stating:

> In summary we have:
>
> - A problematical real-world situation seen as calling for an action to improve it;
> - Models of purposeful activity relevant to this situation (not describing it);
> - A process of using the models as devices to explore the situation; and,
> - A structured debate about the desirable and feasible change (p. 206).

Some artifacts often associated with SSM are:

- Visualization of the problematical situation using "rich pictures" (Berg & Pooley, 2013)
- Using the CATWOE (Customers, Actors, Transformation, Weltanschauung, Owners, and Environment) to develop a generic model to which the three E's—efficacy, efficiency and effectiveness—are added as essential criteria for judgement.
- A root definition that helps in describing the activity systems to be modeled.
- Purposeful activity models with provision for monitoring and control.

A good account of using SSM in practice can be found in Checkland and Poulter (2006).

Suggestion

- It is important to think holistically to choose or construct a methodology that will help in carrying out a systemic intervention. You can either adopt an existing methodology such as ELL or SSM or a general approach such as participatory action research or construct a multimethodological process by combing methodologies as used in TSI that can work together to result is a well thought out meta-methodology.

Methods and Approaches

In order to carry out research you should be familiar with a variety of methods used in conducting research. Some commonly used methods and approaches will be mentioned briefly in this chapter. More about methods and details of their use can be found in good research methods books such as Bryman and Bell (2015), Gray (2014), and Singleton and Straits (2010). Universities conducting research methods courses would also have prescribed books or readings about research methods which you can refer to for more details on specific methods.

Quantitative Research

Quantitative research, in general, adopts a deductive approach that helps test a theory using methods to collect data in objective ways; that is, detached from the source of data. These methods are often used to establish cause and effect and help to generalize from the findings. A quantitative approach often uses experiments or surveys to collect and analyze data. Procedures are usually standardized and carried out using a linear approach. Quantitative researchers work from a positivist paradigm. If you are intervening in systems that often accept quantitative methods, such as healthcare systems, using quantitative methods as part of your intervention could be useful to work with your stakeholders.

Qualitative Research

Qualitative researchers use inductive approaches to generate theory from data. Their research approaches are emergent in design and the researchers are closer to the data. The analysis of data is often subjective or based on interpretation. Data collection uses a naturalistic approach and often involves very detailed, in-depth investigation. Cases to be investigated are often chosen purposefully rather than at random. The emphasis in qualitative research is on exploration or discovery of new themes. Qualitative researchers work from an interpretivist or critical science paradigm. Qualitative methods are very useful when you are trying to find out more about the system you are intervening by collective narratives or interviewing people who are concerned about a problem situation that requires improvement.

Table 5.4 shows some key differences between qualitative and quantitative research approach.

Table 5.4 Key differences between quantitative and qualitative research approaches (Compiled from Bryman, 1988, p. 94; Neuman, 2003, p. 48; D. L. Morgan, 2014, p. 48)

Features	Quantitative	Qualitative
Process	Test hypothesis developed	Discover meaning by immersing into data
Concepts	Distinct variables	Themes, taxonomies, motifs
Measures	Systematically created ahead of collecting data	Often ad-hoc and created for specific cases
Data	Objective	Subjective
	Numbers precisely measured	Meanings and interpretations
		Words, images, observations, and transcripts
Researcher	Detached, distant from data	Close to data
	Reliance on standard protocols	Researcher is the instrument
	Looks to generalize	Looks for depth and detail
	Uses experimental and statistical controls	Uses a naturalistic approach
	Works across a number of cases	Relies on purposively chosen cases
Theory	Causal and deductive	Causal or non-causal and inductive
Procedures	Standardized and replicable	Particular and rarely replicable
Focus	Looks for generalization	Looks for specifics and detail
Analysis	Statistics, Tables, Charts	Extracting themes, organizing data to draw a consistent picture
Reliability	Stability over time	Dependability
	Representative across subgroups	Multiple measurement methods
	Equivalence across indicators	
Validity	Face	Truthfulness
	Content	Authenticity
	Criterion (agreement with external source)	
	Concurrent	
	Predictive	
	Construct—multiple indicators consistent	
	Convergent	
	Discriminant	
Sampling	Probability sampling	Nonprobability sampling
	Random	Haphazard
	Simple random	Purposive
	Systematic	Deviant case
	Stratified	Sequential
	Cluster	Theoretical
Scope of findings	Nomothetic—general law-like findings deemed to hold irrespective of time and place	Ideographic—Locates findings in specific time periods and places

Mixed Methods Research

In the past, researchers tended to use only quantitative or qualitative methods based on the paradigm that they started their research from. Occasionally, they would mix methods for *triangulation* (to have multiple perspectives) but one method would be dominant. However, mixing methods, for reasons other than triangulation, has taken off in the past decade and this approach is being touted as the third methodological movement.

Over the past decade, several mixed methods designs have evolved suggesting one method be used as the principal method supported by a secondary method. These designs also discuss the timing of the use of multiple methods during data collection and/or data analysis. This has resulted in the evolution of sequential, concurrent, embedded, transformative, and multiphase designs. A set of symbols has also been developed to identify each design easily. Due to the evolution of several designs, triangulation has become a less important reason to mix methods. The focus has shifted from triangulation to how the mixed methods research is designed and conducted.

There are a variety of reasons why you would adopt a mixed methods approach (Bryman, 2006, pp. 105–107):

1. Triangulation—to increase the validity of your findings;
2. Offset—To offset weaknesses of one method, draw on the strengths of both;
3. Process—Quantitative methods are useful to investigate structures while qualitative methods are useful to investigate process.
4. Completeness—Conduct a more comprehensive inquiry by using both methods.
5. Different research questions—Each method is useful to address different types of research questions.
6. Explanation—One method is used to explain the findings from the other.
7. Unexpected results—The methods can be fruitfully combined to validate findings when one method results in unexpected results.
8. Credibility—Using both methods could help in the integrity of the findings.
9. Improve the usefulness of findings;
10. Capturing the diversity of views using different methods.

For systems researchers, a mixed methods approach should always be considered to get a comprehensive picture of the system they are intervening in. However, in order to use mixed methods you need to be skilled in both methods or to have access to a team of researchers who are experts in various methods. You also need to be aware of the paradigm in which the method is located as well as its rules so that your research is valid and and/or legitimate.

Books that provide a comprehensive treatment of the use of mixed methods are Creswell (2015), Creswell and Plano Clark (2011), and Teddlie and Tashakkori (2008). A book that covers all three approaches—quantitative, qualitative, and mixed methods—is Creswell (2014), and would help you decide which approach is more useful.

Some questions you may ask to decide on the use of the type of methods in your research project are:

- What is the primary reason for you research—exploratory or to establish cause and effect?
- Are you comfortable to work across paradigms?
- Does your research involve several phases?
- What are the skill sets in your research team?
- What type of access do you have to your research setting?

Conceptual Framework

According to Maxwell (2013), it is important to start with a conceptual framework for your research that links "the system of concepts, assumptions, expectations, beliefs and theories that supports and informs your research" (p. 9).

You were introduced to some frameworks in Chapter 2 that could be the basis on which you can build your conceptual framework modified to suit your design. A model that you build for your research from the ideas presented in Chapter 4 can also be useful for developing a conceptual framework.

Maxwell (2013) suggests using the following ideas to build your conceptual framework:

1. Experiential knowledge based on your own personal knowledge and experience can be useful to form a framework in your mind;
2. Prior theory and research that includes other people's theories and research;
3. Visual tools such as concept maps based on a theory relating it to the phenomenon you are studying or representing the design and operation of your study;
4. Pilot and exploratory studies that you conduct prior to starting your main research project that provide some insights; and,
5. Thought experiments or speculative model building, often used in science, trying to build plausible explanations for your observations.

Figure 5.7 shows an example of a simple conceptual model developed by Pinzòn and Midgley (2000, p. 506) as a high-level conflict structure.

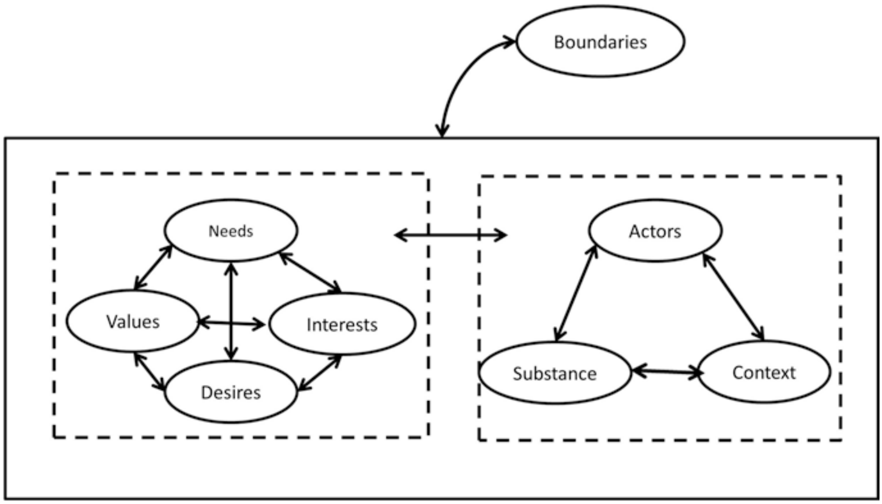

Fig. 5.7 A conceptual framework

Negotiating Relationships

It is not always easy to gain entry to conduct research at a site or setting where you want to conduct your study. Often you have to negotiate entry with gatekeepers to gain access. It is therefore important to do a stakeholder analysis at the start of the research to evaluate the power and influence of stakeholders as well as their attitude towards your research project. It is also not enough just to gain entry but you need to put in place strategies to maintain access by renegotiating access, as and when needed, throughout the project (Dick, 2002). Some questions you may like to ask are:

- Who will be involved in the research?
- What level of involvement will they be offered?
- Within what constraints will the research operate?
- Whatever the roles and processes negotiated, how much flexibility exists?

Data Collection Strategies

In order to conduct your research you should be familiar with data collection strategies that are commonly used.

Suggestion

- Have you been taught research methods at your university or institution? Reviewing that could be a good starting point.
- Do you have opportunities to observe experienced researchers in action? That would be a good opportunity to improve your technique.
- Pilot field work or studies would help as well. If not, are you able to get videos from your library demonstrating the use of research methods?
- Have you searched for YouTube videos on a particular data collection method?
- Testing methods new to you through role playing and simulation may help strengthen these skills and build confidence.

You have already been provided some references to books on quantitative, qualitative, and mixed methods that provide more details on data collection strategies. There are also books explaining specific data collection strategies, for example, focus groups, conducting surveys, constructing questionnaires, interviews, and so forth. Table 5.5 lists some common methods used in data collection with references to books that provide more information on methods used in conventional research giving examples of how they can be used in systems research.

Table 5.5 Data collection methods commonly used

Methods	Main use	Use in systems research	References
Experiments	Often used for testing in the sciences but also used in social sciences	Pre-post testing with experimental groups and control groups often used in healthcare	Shadish, Cook, and Campbell (2002)
Survey questionnaires	Provide information that can be collected anonymously (when it is important) and analysed using statistical methods	Collect information from a wide variety of people (often inaccessible) in a cost effective way. Helps to generalise findings when it is required	Fowler (2013); Saris and Gallhofer (2014)
Interviews	Often used in qualitative research but can also be used as a structured instrument to collect quantitative data	Very useful to gather preliminary information to identify factors that are creating a problem situation. Often used in case studies that may be part of a systems intervention	Kvale (2007); Rubin and Rubin (2011)

(continued)

Table 5.5 (continued)

Methods	Main use	Use in systems research	References
Focus group	Collect data efficiently from a group of people	Multiple perspectives can be debated and collected in a systems intervention. Useful to collect pilot data and also to confirm/disconfirm findings	Krueger and Casey (2014)
Observation	Collect naturally occurring data. Can be unobtrusive or participant	To collect information as they occur and not based on past memory or interpretation. Always useful if there is time and opportunity to ascertain facts	Spradley (1980); Glesne (2016)
Narratives and storytelling	Gaining popularity and useful to collect data across cultures	Useful to collect data from cultures valuing the oral tradition. Often provides deeper insights than interviews	Maitlis (2012); Czarniawska (2004)
Visual methods	Becoming common due to availability of affordable equipment	Systems researchers often use visual methods naturally in the form of pictures and diagrams. Recording events visually is useful in specific contexts and they can be replayed even after leaving the research site	Emmison, Smith, and Mayall (2012); Banks (2007)

Other Useful Methods

We will not go into details of other methods and approaches, but it will be good to know about the following as they can be used to construct your methodology.

Case Study

Case studies for exploratory, descriptive, or explanatory purpose using a single, embedded, or multiple case study design are a well-established qualitative research method. Case studies have the advantage of being able to use multiple sources of evidence and investigating contemporary events over which the researcher has no control. They are useful when you have "how" and "why" questions. Good books to learn more about case studies are Yin (2014) and Stake (1995).

Grounded Theory

Grounded theory is one of the methods where data collection and analysis are simultaneously carried out to develop theory. Grounded theory emphasizes collecting rich data through intensive interviewing and uses analysis techniques such as open and axial coding, and memo writing. Good references are Glaser and Strauss (1999), Corbin and Strauss (2015) and Charmaz (2014).

Sampling

Sampling is an important aspect of setting up any research. Sampling is approached differently by quantitative and qualitative researchers. Quantitative researchers use probability sampling while qualitative researchers use non-probability sampling.

Books on qualitative and quantitative methods will provide guidance to sampling. A good treatment can be found in Chapter 8 of Neuman's (2003) work, *Social Research Methods: Qualitative and Quantitative Approaches*.

Data Analysis

Once data are collected, they have to be analyzed to find answers to your research questions. In some approaches, such as action research, constructing grounded theory, or in the use of multiphase research, data are analyzed in stages during the research. Several good books are available to help you learn more about data analysis such as Bazeley (2013), Cramer (2003), Miles, Huberman, and Saldaña (2014), Silverman (2011), and Vogt, Vogt, Gardner, and Haeffele (2014).

Statistical Analysis

Quantitative data is normally analyzed using statistical techniques. Software packages can make your job easier if you learn them as part of your research training. Statistical packages such as IBM-SPSS (http://www-01.ibm.com/software/analytics/spss/products/statistics/), LISREL (http://www.ssicentral.com/lisrel/), and PLS-SEM (http://www.smartpls.de/) can be used to help you with statistical analysis of data.

Qualitative Data Analysis

Qualitative data analysis typically uses content analysis or coding techniques to derive themes. Software packages such as NVivo (http://www.qsrinternational.com/), Atlas.ti (http://atlasti.com/), Leximancer (http://info.leximancer.com/), and WordStat(http://provalisresearch.com/products/content-analysis-software/wordstat-features/) are useful for qualitative data analysis.

Using Participants to Analyze Data

In some cases, it will be valuable to get participants to analyze data under your guidance. An interesting example of how to use systems methods to get participants to interpret their own data is provided by Burns and Worsley (2015, p. 70). The local Community Based Organizations (CBOs) had collected 350 stories in a research project investigating bonding and slavery in India. The people from the CBOs were then divided into pairs by the researchers and the stories were divided among them. They were then asked simple questions to develop causal relationships from the stories. Once all stories were analyzed the people started mapping the linkages on a large wall covered with paper using system maps. This helped the linkages from several stories to be viewed in one place visually in a short time. Once the basic maps were in place, the facilitators asked the participants if they felt that some lines should be thicker than the others to identify stronger linkages and also put stars on items of conflict. Other symbols like question marks were also used. This led to seeing patterns in further investigation.

Rigor

The way rigor of the research is demonstrated also varies with the type of research methods used.

Reliability and validity are key issues in quantitative research to confirm measurements and results. Reliability measures dependability by looking at the stability of results over time and representation across different groups. It includes gauging the reliability of the indicators used in the research for consistency. Validity seeks to confirm the goodness of measurement, that is, whether you are measuring what you intended to measure. Measures used to check validity include face validity to confirm that the constructs are helping us to measure the concept intended. Content validity aims to ensure that the measures are covering all facets of a concept. Criterion validity helps to ensure confidence that the researcher is using the right measure through comparison with a standard. Construct validity looks to confirm if the instrument we are using is measuring the intended concept.

Qualitative researchers are more concerned with credibility of "description, conclusion, explanation and interpretations" (Maxwell, 2013, p. 122). Qualitative researchers have to be aware of bias as they use subjectivity and interpretation. They have to be careful to ensure that they do not select data to fit their own preconceptions. They should also be careful about the influence they have on the setting or the subject they are studying. Some qualitative researchers use Lincoln and Guba's (1985) evaluative criteria of credibility, transferability, dependability, confirmability, and authenticity.

Qualitative researchers also use quality criteria to explain the rigor of their research (see Flick, 2008).

It is also recommended to document the methodological process you used and how it varied from your original design.

Suggestion

- It is important to argue for the rigor of your research from the way it is set up and the manner in which your conclusions have been derived. You can use the traditional concepts of reliability and validity or use the criteria used in qualitative research that confirm the credibility of your research. You can also argue from a quality perspective. It is important to define the criteria for ensuring the rigor of your research at the start and ensure that they are being followed during the research. I have seen researchers often think about these when writing the report but it is often too late. Get an early start on how you are going to ensure the rigor of your research.

Ethics

Ensuring that you are conducting your research ethically is very important. There are institutional requirements to secure ethics approvals before you start your research. There are also special ethical considerations to observe while conducting systems research. Chapters 1 and 6 discuss more about ethical practices.

Summary

Taking action often requires you to intervene in a system to introduce change. You have the responsibility of carrying this out professionally and ethically. Planning how to conduct your research will go a long way to ensure that you meet your obligations as a responsible researcher.

This chapter has provided you guidance on getting started using a variety of strategies. It has also explained how systems interventions are designed using some actual examples. It has given you an overview of the nitty-gritty of the conventional research process covering a variety of methods, as well as data collection and data analysis strategies. It has emphasized the importance for demonstrating the rigor of your research as well as being aware of ethical issues.

The chapter has tried to cover a lot of territory in a small space. It has also provided you several references if you want to dig deeper. Although you may have attended research training at your own institution or elsewhere that has more comprehensively covered research methods and processes, the emphasis in this chapter has been to show how and why they are relevant to systems researchers.

Essential questions you may want to ask are:

- How do I set up my research project to answer my research questions?
- How will I design my interventions systemically?

- What do I have to know about research methods and use them well?
- What is the scope of the research?
- How do I convince my readers that I have carried out my research rigorously and ethically?
- What contribution does my research make?

The next chapter will guide you on how to report your research.

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Chapter 6
Systems Research Reporting

Will Varey

Abstract The competent design, planning, undertaking, and analysis of systems research deserves to be reported well to reflect its systemic strengths. The very best systems research will evidence a systemic approach in its structure, content, and overall contribution to the field. To enable a systemic approach to systems research reporting, a researcher must frame and select from a number of considerations specific to the systems field. This chapter provides clear guidance for systems researchers in a systematic approach to writing up and reporting research in the systems sciences. The distinctive roles, forms, levels, phases, and premises of systems research are outlined for consideration. A systematic approach to reporting highlights the elements of structure, boundary, relations, timing, and completeness that assist favorable evaluations. The researcher is also directed to the critical choices they must make between systems definitions, paradigms, voicings, and perspectives. The chapter concludes with a consideration of common errors of omission and the unique ethical tensions experienced when undertaking contemporary systems research. This content will benefit early career systems researchers, research article reviewers, examiners of dissertations, and experienced systems practitioners in making their own contributions to the wider systems discipline.

Keywords Systems theory • Research reporting • Systems research • Boundary definition • Ontological frame • Systemic thinking • Systems ethics

Approaches to Reporting Systems Research

The previous chapters of this book (Chapters 1, 2, 3, 4 and 5) outline many necessary considerations for the researcher when conducting systems research. These considerations include systems definition, framework selection, problem structuring, research design, scenario modeling and systemic intervention. This chapter

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M.C. Edson et al. (eds.), *A Guide to Systems Research*, Translational Systems Sciences 10, DOI 10.1007/978-981-10-0263-2_6

considers the unique decisions taken by systems researchers in communicating and reporting the results of their systems research. The writing up of your research will reflect your competency in systems research (see Chapter 7). The thoughtful reporting of your systems research enables the favorable evaluation of that research (see Chapter 8). In this way, the writing up and reporting of systems research can provide benefits for the researcher and to the systems research discipline equally.

The role of this chapter is to guide you in your writing up and reporting of systems research. It highlights the critical choices you will need to make and how these inform the reporting process by proposing a systemic approach to communicating research. The focus is on what is uniquely different about research reporting in the systems disciplines. This will help you communicate your research to systems literate and non-systems expert reviewers with ease and clarity. This chapter also adopts a systems approach to this topic to illustrate the principles of systemic inquiry.

This chapter is structured using five main themes:

- Features unique to systems research reporting;
- Systemic approaches to composition and balance;
- Choices in reporting and writing-up systems research;
- Common errors of omissions in systems research reporting; and
- Ethical considerations in undertaking systems research.

The chapter will benefit early career systems researchers and doctoral candidates in planning their research. It will assist researchers who find they have a systems component when doing research in other disciplines. The discussion will provide article reviewers and examiners of dissertations with confirmation of the critical elements to look for. The chapter may also highlight new considerations for the experienced systems practitioner and for the systems discipline itself. Our discussion commences with an overview of some important questions and consideration of the difficulty of attaining a balance when meeting competing demands.

Questions in Systems Research Reporting

The systems sciences can be seen as representing an identifiable and established field of research (von Bertalanffy 1968, 1972; Hammond, 2002). Systems research may also be conducted within the conventions of other formal scientific and research disciplines (Klir, 2013). Excellent guides already exist outlining the forms and conventions for writing up research in those disciplines (see Chapter 5). If you adopt a systems approach to your research certain features not usually considered relevant will become important and significant. This chapter focuses only on the features specific to *systems* research reporting. It concerns the considerations and inclusions additional to those required by other disciplines. It will help you isolate the questions unique to systems research reporting.

Some of the critical questions covered in this chapter include:

- What is the role of systems research reporting?
- How is systems research distinguishable from other research?
- How can I plan to write up my systems research adequately?
- What are the key reporting considerations and how should I approach them?
- Why are the choices of voicings or voice, tense, stance, and tone so important?
- What will good systems research ideally show to assist favorable evaluation?
- What else does a researcher need to consider when making reporting choices?

To answer these questions, this chapter consciously adopts a systemic analysis. By doing so the intention is to enhance the critical reflexivity of systems researchers when reporting on their research. Topics covered in this chapter include:

- The critical questions asked in systems research reporting;
- The choices of balancing competing tensions in writing up;
- The distinctive roles for systematic, systems, and systemic research;
- The three forms of systems research as context, content, and concept;
- The abstraction of systems analysis as levels of critical inquiry;
- The phases of scientific research (as a system) and its validity claims;
- The principle of concordance in designing systems research efficacy;
- The consideration of the systemic elements in research composition;
- The choice in meanings, paradigms, and complexity in systems research;
- The benefits of finding consistency in voice, tense, stance, and tone;
- The common errors of omission seen in competent research reporting;
- The ethical considerations unique to reporting in the systems sciences;
- The role of systems research in enabling humanity contributive knowing.

To allow you to navigate this vast territory there are clear signposts to help you. Each section of the commentary is supplemented by suggestions for best practice. Rather than being prescriptive, these suggestions prompt you to check your thinking and engage in reflective practices. This is done with the view to empowering you as a researcher to make your own research reporting decisions. The hope is to enable your awareness of the flexibility of choices possible (and the implications of your choosing). This provides you with more than advice, being the pathway to self-guidance (Richmond, 1993). In walking that pathway you will naturally see how the reporting stage helps link the research process from conception, formation, observation, moving through to publication.

Balance in Systems Research Reporting

There is no simple guide to the balancing of composition in research generally, or systems research specifically. The perfect mix between describing theory, process, data, analysis, and findings depends on the novel content and specific context (Creswell, 2012). Hints from standard reporting and style guides suggest being "convincing," "clear," and "brief" (Merriam, 2009), while also balancing "description and interpretation" and "commentary and illustration" (Ritchie, Lewis, Nicholls, & Ormston, 2013). The reporting requirements for qualitative, quantitative, and mixed methods research are specific, prescriptive, and possibly contradictory (Midgley, 2000).

In *systems reporting* there will be additional information to include, such as system definitions, framework explanations, scenarios models, novel interventions, and speculations on dynamics. In a review of many articles using a broad range of systems methodologies the reporting of systems research can appear to be idiosyncratic, with each case relying on its own paradigms of practice. Your main aim in doing systems research reporting well is to ensure that the systems elements of your research are easily identifiable for your intended audience. Like all systems work, this involves finding a systemic format that balances all the tensions, between different components, within one comprehensive structure. To do this well you will need to resolve some clear contradictions, especially those of meeting the needs of different systems audiences (i.e., systems-literate and non-systemic thinkers). Ideally, a systems approach to systems reporting enables all the parts, and the whole, to work elegantly together in the intended contexts.

Some crucial tensions and choices for systems reporting include:

- Speaking to abstract forms and intangible dynamics, concretely;
- Using frameworks to guide an inquiry, recognizing what they omit necessarily;
- Describing the full systems context, without losing the points of focus;
- Including all components of relevance, while noting elements of significance;
- Having rigor in the main methodology, within a flexible mode of inquiry;
- Treating the system as being complete, while recognizing a wider totality; and
- Meeting the level of complexity of the system, but describing this simply.

The following sections give a guide on how to balance these tensions and approach these reporting questions. This will enhance the communication of your (already proficient) research distinctively.

Features Unique to Systems Research

> Sometimes half a dozen figures will reveal, as with a lightening flash, the importance of a subject which ten thousand labored words, with the same purpose in view, had left at last but dim and uncertain.
>
> —Mark Twain, *The wit and wisdom of Mark Twain*

If we take a moment to reflect on the question, "What is unique about systems research?" it is not surprising that doing system research generates questions about the forms and functions of research itself. There are three systemic features that become immediately apparent in a systems context. These relate directly to (a) the appropriateness of the research form, (b) the structure of the parts, and (c) the efficacy of the whole. These three considerations are central to a systems approach generally. The systemic elements of the research itself can be analyzed similarly. They highlight the *concept*, *composition*, and *concordance* of the research process being reported. Together these constitute a useful systems research aesthetic.

An aesthetic test for reporting on systems research is to confirm the researcher has considered these features by identifying: the systemic boundary (of assumptions), the system of relations (in the composition), and the totality of effect (from their combinations). An elegant piece of systems research will potentially have each of these elements in harmony. For the systems thinker, elegant research has a balance in these elements intuitively. The skillful systems researcher may even embody *systemic beauty* in their research design consciously. When conscious design is explicitly followed throughout the conduct of the study, this balance serves as a meaningful locus for coherence. The resulting reporting will ideally synthesize analysis and integrate findings to form an erudite and resonant discussion.

Research that is confused as to its boundary of inquiry, that is missing critical and obvious components in the report itself, or that does not function logically as a totality, cannot be looked upon favorably. Part of doing good systems research is knowing what a good systems researcher looks for. A special opportunity presents itself in the reporting phase of the research. This moment allows you to view your research by standing outside of the system of research itself, to examine its composition, and to check how it functioned as a research system. The critical reflexivity, to do this inquiry adequately, is the main focus of this section. An appreciation of the difference between systems roles, forms, levels, phases, and premises will help you in this reflective task.

Roles of Systems in Research

The question asked is: What are the reporting formalities that enable systems research efficacy? Considering all of the critical choices described in the prior chapters (i.e., systems definition, framework selection, problem definition, research design, modeling options, and forms of intervention) arguably the role of systems reporting is actually the most important in conducting good systems research. The reason for this statement is that until a systems inquiry is reported, in ways that can be recognized and validated by its community of peers, it is not research. It is the formalities of the reporting conventions in research disciplines that allow personal inquiry and experimental actions to be verified as contributions to the knowledge commons. By following these conventions you allow your research to be recognized fully.

Otherwise sound systems work that reports its findings only selectively, without rigor in its composition, or the possibility for evaluation, may not be considered to constitute valid research. Arguably, such examples are at best a recording of personal reflections and opinions, and at worst an advertisement for unsupported viewpoints. To constitute research there are requirements for writing up and reporting. There are also formal (and informal) requirements that delineate systems research from other forms of research reporting.

Foundationally, the basics for writing up academic research in each of the major disciplines will apply to systems research when conducted within those disciplines. The inclusion of systems concepts, within research primarily conducted within an established discipline, will not exempt the researcher from adherence to that primary discipline's baseline standards of research reporting. The many research handbooks provide clear guidance on the requirements of such research fields, with some examples being:

- Handbook of Innovation in Social Research Methods (Williams & Vogt, 2011)
- Handbook of Qualitative Research (Denzin & Lincholn, 2011)
- Handbook of Mixed Methods in Social and Behavioral Research (Tashakkori & Teddlie, 2010)
- Handbook of Organizational Research Methods (Buchanan & Bryman, 2009)
- Handbook of Research Synthesis and Meta-Analysis (Cooper, Hedges, & Valentine, 2009)
- Handbook of Systems Engineering and Management (Sage & Rouse, 2009)
- Handbook of Quantitative Methods: Health Science (Peat, Mellis, & Williams, 2002)
- Handbook of Research Design and Social Measurement (Miller & Salkind, 2002)
- Handbook of Action Research: Participative Inquiry and Practice (Reason & Bradbury, 2001)
- Handbook of Applied Social Research Methods (Bickman & Rog, 1998)

Rather than précis or paraphrase this existing guidance, we can instead examine the specifics of reporting for systems research. The proposition is that the inclusion of systems concepts in any research provides *additional* demands on the standards of reporting, the assumptions that may be made, the format for research reports, and the conclusions that may be validly drawn. In support of this suggestion, it is useful to distinguish how the use of systems ideas provides three distinct and important roles in research (generally):

- *Systematic processes*: the contribution of the systems sciences in informing and formalizing systematic approaches to reliable and repeatable research procedures.
- *Systems descriptions*: the use of concepts, formal terms, and descriptive language that researchers may use to define and describe the systems they are researching.
- *Systemic understanding*: the role of systems thinking in linking causes and effects and connecting contingent factors when examining a specific phenomenon in an identifiable situation or context.

These different systems roles change the reporting of research outcomes. Systematic processes in non-systems disciplines provide tests of rigor. Systems descriptions will follow frameworks and their presumptions to demonstrate the efficacy of those applications. Systemic understanding allow for novel inquiry by mastery of systems thinking in lineages of philosophy. The blurring of these roles might mean the research is seen to be (in each case) as lacking in rigor, efficacy, or mastery. Being clear as to the chosen role systems ideas take in your research will allow you to blend these roles appropriately.

Suggestion

- Consider the role of "systems" in your proposed research and how that role will be ultimately best fulfilled. Other than calling it a "system," what is there to evidence systematic processes, systems frameworks, or systemic concepts? If the idea of a system is used only informally, how will your research be viewed when considered by a systems-literate community?

Forms of Systems Research Emphasis

Given the different roles of systems research in establishing *systematic* process, *systems* descriptions, and *systemic* understandings, it is important to characterize three forms that systems research may take in fulfilling those roles. Each form has a very different emphasis. This alters the primacy of system concepts in the research performed. For convenience, these three primary forms of systems research are:

- S*ystem as context*—the skillful research done within an existing and identified system (e.g., health systems, ecosystems, accounting systems, software systems, financial reporting systems) adopting usual research processes (e.g., empirical analysis, social research methods, error identification by audit, etc.)
- *System as content*—research having as its focus the understanding of a system, its components, and dynamics (e.g., health care procedures, ecosystem modeling, evaluating software design, planning for urban services), probably using systems theory methodologies and frameworks developed in the systems research paradigm (e.g., general systems theory, viable systems modeling, soft systems methodology, system dynamics analysis).
- *System as concept*—the research done into the efficacy and proficiency of systems theory itself, specifically looking at the assumptions, applications and extensions of systems theory as a research discipline and the efficacy of its practice paradigms across multiple disciplines (e.g., general systems theory, complex adaptive systems theory, complexity theory, hierarchy theory, panarchy theory, systems ontology).

The distinctions between these three forms of systems inquiry require the researcher to allocate significance to the systems research elements in ways appropriate to the research conducted (i.e., system as *context*, system as *content*, system as *concept*). While these distinctions may be arbitrary, with good research containing a mix of one, two, or all three forms, there are different expectations on the critical analysis of the system elements required for each of the three forms. The implication in writing up the research is to ensure the rigor adopted matches the chosen systems emphasis.

For example, research within a system needs to recognize the system's distinctive existence by identifying it as a definable system. Research using systems theory needs to reference systems thinking formalities, comprehensively and accurately. Research about systems research requires a higher order of abstract logic, to consider the premises of systems research itself, as a discipline of inquiry. The use of ill-defined system reifications, poor framework applications, or uninformed systems speculations will create noticeable omissions in otherwise good research applications. While the choice of best form will be the one most appropriate to the research context, clarity about the form of your intended contribution will mean that significant amounts of underpinning theory may be omitted knowingly. The researcher's main obligation is to be clear about how *systems* are used in their research and to allocate the commensurate degree of systems analysis.

Suggestion

- Being clear about the form of systems research being undertaken means the expectations of reviewers, as to which questions are examined (or left unexamined), can be applied more reasonably.

Levels of Systems Research Inquiry

In addition to the *roles* and *forms* of systems research, it is worth considering the *levels* of research reflexivity appropriate to your inquiry. Cyberneticist and systems theorist, Gregory Bateson (1972) described iterations in the logical categories of types of learning (i.e., Learning 0—Learning IV). Those distinctions can be usefully applied to systems research and its analysis. For this specific purpose:

- *Learning I* operates when the active recognition of good methods enables new information to be gathered effectively without error repetition.
- *Learning II* occurs when the process of gaining new information is itself questioned and then refined or revised by forming alternative methods.
- *Learning III* occurs when the paradigms and assumptions informing the choices of the design of methods are themselves reformulated.

Later characterized as "double-loop" and "triple-loop" learning (Tosey, Visser, & Saunders, 2011), the practice of reflection on each of these levels of abstract logics enable the "system of the system" for research to be actively researched. The level of learning aimed for and actually adopted changes the expectations of the research considerably (and the validity claims that can be made correspondingly).

For example, a researcher may use an existing test instrument to find out about changes in learning occurring in an education system (Level I). In examining that data, new questions may arise as to whether a learner's age or developmental stage provides the better systemic premise for measurement (Level II). From this analysis, questions may arise as to whether the premise of how learning occurs systemically may then also require re-examination (Level III). This may lead to a systemic reconceptualization of the idea of learning, the structure of its key components, and the methods for its assessment. While all these forms of study are valid, each will direct the researcher to different categories of systems content.

Even when the format of the reporting may be firmly established by the paradigm of practice adopted at the commencement of the research, the significance of the final systems emphasis of the research can be initially unclear. When formulating the research question the level of systems analysis is often not known. The researcher may find, in using systems methods, that the assumed and fixed elements of existing systems become openly questioned. It may be we are looking at the wrong system, or the right system is being looked at wrongly. The point is that this natural shift of the level of systemic focus during the research dramatically affects the research and its resulting reporting.

Suggestion

- Consider the permitted assumptions for both the system being researched and the system of permitted research. Check if the form of reporting requires uncritical acceptance or allows for challenges to assumptions. If the level of inquiry shifts during the research, the research emphasis (and the content considered adequate) may also need to change. This unexpected change in emphasis is a natural trajectory of good systems research, which can be actively and consciously embraced

Phases of Systems Research Method

In addition to decisions about clarifying the specific roles, forms, and levels of your systems research in your research reporting, there is a further overall consideration. This is the recognition that research is itself a system in iteration. Traditionally, research methods have been divided into three primary domains: *deduction*, *induction,* and *abduction* (Magnani, 2001). Karl Popper (1959, 1972) proposed that these three distinctive phases of research work operate as an entire system, with a grounded hypothesis (i.e., abduction), becoming proven or disproven (i.e., deduction), and its extensions then tested (i.e., induction), for pragmatic and beneficial outcomes. Deduction extends existing assumptions. Induction expands on existing applications. Abduction initiates novel innovations (Varey, 2012). Each has their appropriate uses as well as specific strengths and limitations and (see Chapters 1 and 3).

These three different phases of research also have different reporting requirements, which relating to the limit of the knowledge-based claims that the phase of the research makes possible. The respective validity claims can be summarized as:

- *Deductive*: Due to specificity of the context and constraints, claims can be made about the conclusiveness of findings for that situation (i.e., because X was considered assuming Y, we can conclude Z).
- *Inductive*: In reporting on the basis for comparison, claims can be made about the validity of extensions and scope of applications (i.e., because X is like Y, we can possibly say Z about Y).
- *Abductive*: By analysis of the general features of the broad case, claims can be made about possible principles and their relations as hypothesis formation (i.e., because of Z occurring in case X, we can assume Y).

This distinction is often overlooked or historically assumed for other disciplines. For example, deductive empirical studies may begin with a hypothesis, inductive social studies often commence using a comparative narrative, and systems engineering and computational logics may begin with only a few abstract parameters. The development of systemic understandings can be less prescriptive in the wider fields of systems research. The formation and modeling of a system can involve descriptive exploration, abductive investigation, and active co-participation to find the best possible alternative from many combinations. The forming of a novel systems conception by abductive methods will provide a premise for later critical evaluation, practical testing in known situations, and the possibility for future extensions to new applications. The role of formal abductive logic is central to good systems research generation (Aliseda, 2006; Rozeboom, 1997). The intended *phase* of system research deserves specific noting and requires corresponding rigor in its processes of reporting.

Suggestion

- Consider the phase of your research. If claims of a deductive proof are made, ensure the hypothesis uses assumptions that are reliable and are established for that system. If an inductive extension is claimed to be valid, confirm that the comparison is of systems that have equivalence in structure and/or function. If the research is abductive and novel, ensure that the tests for valid abductive logics have been explained and are reported adequately.

Premise in Systems Research Design

In advanced applications of systems research, while the consideration of role, form, level and phase is relevant—there is also a need for systemic functionality in the formation and execution of the research method itself. It is this particular feature of good systems research that allows for the discovery of the undiscovered, the illumination of the hidden, and the validation of the previously unimagined. Mature systems researchers may use a systemic analysis of their research premise to formulate new paradigms for practice in scientific understanding (Kuhn, 1974).

In following the history of the development of systems theory (see Chapter 1), we can recognize the distinctiveness of systems philosophy, its premise of epistemology, the unique use of methodologies, and the nuanced qualities of inquiry that combine to represent good systems research. In mature research fields the assumptions of how good research is done has been long established. The alignment of the understanding of reality, the ways of knowing, the methods for gaining information, and the manner in which this is communicated are clear, precise, consistent, and static.

For the systems researcher, the many forms of systems (e.g., natural, social, ecological, physiological, cosmological, theosophical, virtual, and their conjunctions) mean the premise of validity in research forms is not so predetermined. However, the way in which research choices form and shape a systematic research approach can be examined systemically. This "systems approach to systems research" is described as the testing of philosophical concordance (Varey, 2013). The proposition is that good systems research design should ostensibly contain an alignment between the philosophically critical elements adopted for good researching.

For example, in the field of social systems research, Creswell (2012), extending on the work by Guba and Lincoln (1994), proposed five categories that social researchers may consider in formulating their research design. These five dimensions are the: (a) ontological; (b) epistemological; (c) methodological; (d) axiological; and (e) rhetorical assumptions of the research. The suggestion is that good social research involves an inquiry into "choice sets," not simply to establish research completeness, but also to formulate research proposals that have efficacy across these five dimensions.

In examining ecological and hierarchical systems, Ahl and Allen (1996) have proposed a similar requirement for alignment, focusing on the tensions between five components. They identified five "junctures" in an iterative process "at which an observer's decisions are crucial to structuring an observation" (Ahl & Allen, 1996, p. 35). Those sets of choice are framed as: (a) question formation, (b) entity definition, (c) measurement selection, (d) phenomena recognition, and (e) modeling predictions (Ahl & Allen, 1996). This approach highlights the reciprocity between the observer and the observed in a constructivist approach to the design of systems research. A similar level of definition may be appropriate for a constructed approach to novel and dynamic systems, in systems engineering, systems software design, or for the formulation of virtual systems.

In writing-up systems research, the report of the research will ideally (even if briefly) situate the choices of: (a) system philosophy, (b) epistemological framework, (c) systems research methodology, (d) paradigm axiology, and (e) form of system depiction, as components within a totality. The researcher should justify each selection with reference to the other elements of composition. In this way, the research as a whole may be considered to include "informed, relevant, appropriate, significant, and representative" elements (Varey, 2013).

This simple test enables the evaluators of the research to confirm the research design has the elegance of philosophical concordance. Omissions in the alignment of any one of five forms may constitute a critical research design error. This will be clearly apparent. The systems reviewer will necessarily inquire to confirm whether the research:

- Assumes a certain systems philosophy, without any form of prior inquiry;
- Relies on a framework epistemology, in conflict with contextual reality;
- Adopts a default methodology, not useful for the intended discovery;
- Overlooks inputs of axiology, to omit or negate factors of significance; and,
- Represents a schema simplistically, hiding relevant levels of complexity.

Of course, research that is concordant in its approach may still be completed ineffectively with nothing to show for the efforts, and research with these critical design questions omitted may be done exceptionally well, also yielding remarkable results. More frequently, without any critical analysis of the assumptions that inform the research premise, the reviewer or examiner is left perplexed at the certainty of the conclusions reached by the researcher and will be unable to assess the validity of the system of research adopted (Ulrich, 1983).

While peers and colleague researchers may have a preference for a different general systems philosophy, a personally resonant epistemology, familiar research methodology, standard tests of inclusivity, or an iconic form of system representation, to be considered *research* in the systems discipline, a valid analysis requires more than assertions of personal preference. The ability of the researcher to assemble the parameters of their research with efficacy also says a great deal about their systems research ability.

Suggestion

- It is a courtesy to reviewers holding a different preference in systems methods to explain the choices of components adopted in your research approach, how they relate in the research context, and what (by definition) they must include, omit, or reveal to enable the critique of the premise adopted for the systems research.

Systemic Approach to Composition

> The time to begin writing an article is when you have finished it to your satisfaction. By that time you begin to clearly and logically perceive what it is that you really want to say.
>
> – Mark Twain, *The wit and wisdom of Mark Twain*

The diverse application of systems thinking in many research fields means there is a plurality of forms for systems reporting. Where a research paradigm (whether quantitative, qualitative, mixed method, or multi-method) requires set sequences it can be seen as having a *systematic* approach. The use of methodical procedures and handbook checklists, while systematic, may not be *systemic* (Ison, 2008). The distinction made here is that applying a rigorous process, to a complex situation, may not involve the use of systems thinking processes. Adopting the idea that the research concerns "a system" is not synonymous with using a "systems approach" as the research method (Checkland, 1999). Arguably, to be good systems research, systems ideas, principles, and concepts should be used for organizing the actual research itself.

The proposal of this section is that systems research must not only follow a system, but the components of the research, the sequence of research steps, and the resulting compilation of the research should also reflect a systems approach. While this is not strictly necessary for research making use of systems concepts unsystematically, it is possible that *good* systems research should reflect a systems philosophy. The following sub-sections will highlight the basic systems concepts that make systems reporting a *systemic* (as opposed to simply a systematic) activity.

Structure: Limits of System Framework

The structure of a system is discernable by the distinction of its parts. For systems reporting the components of the research report must be clearly identifiable. The standard quantitative reporting components of *research question, literature review, method design, experiment results,* and *research conclusions* provide a clear list of components for students. However, while making clear distinctions, this listing itself does not explain the *system* of the research.

When doing research into systems, whether naturalistic or human designed, the researcher will usually find a linear and idealistic process might not match with the systemic realities. The effect is that the process of method design may be iterative, with a need for recurrent sampling, reflections on action research questions, time to observe the effect of change from interventions, and the modeling of alternatives leading to further novel trial experiments.

The proposition is that some of the best systems research is by definition "systemic" and so cannot be pre-designed to be systematically consistent (Ison, 2008). At some point in examining dynamic, emergent, evolving systems, linear reporting processes can no longer serve the paradigm of their inquiry. For this reason, the *system of the research* adopted may need to be explained more as a sequence of causations, which should be transparently outlined by a clear description of the stages and their components as they were performed. There is often a systemic logic to the systematic discovery of systems features (Simon, 1977). The systemic approach is rational and defensible, even if not necessarily seen as being linear, prescriptive or predictable (Checkland, 1999).

Boundary: Inclusion of System Participants

It is sometimes claimed that systems research approaches are (by definition) more holistic and inclusive (Hall & Fagen, 1956; Jackson, 2003). The systems approach suggests that by simply looking at objects in a context, its research methods are more universal by holding a potentially wider perspective (Meadows & Wright, 2008). However, the mature systems researcher knows acutely that studying a system also involves making informed (yet arbitrary) judgments of limitation (Ison, 2008).

A system is often defined precisely and clearly for research purposes. The usefulness of the research is restricted by its implicit limitations, which are a function of what it explicitly includes (and excludes) in its considerations. The ethical systems researcher will also recognize the effects that boundary judgments play in inclusions (and marginalizations; Midgley, Munlo, & Brown, 1998). To make any valid statements or conclusions, good systems research should be explicit about its processes for boundary definition, delineation, and extension (Midgley, 2000). Even if mostly an abstract theoretical hypothesis, the research strength of a system analysis lies in the descriptions of the boundary of its intended valid use, and the obvious resulting exceptions to which it has no application.

Relations: Sequence of Research Actions

The obvious addition to considerations of structure in a system of research is the need to make explicit the dependent links between the research components within that structure. Generally, systems involve patterns of interconnections (Bateson, 1972; von Bertalanffy, 1968). However, it is the strength and pattern of relations between those interconnections that give a complex system (and its sub-systems) the characteristics of an identifiable system of significance (Maturana, 1981; Simon, 1962).

Systems reporting requires more than completion of a formulaic list. As the inquiry generates emergent information, the system of reporting may also require reformulation. The understanding of how choices of selection at one stage of the research inform and affect outcomes and opportunities at other stages of the research shows a systemic understanding. As an example, one purpose of this book is to assist the systems researcher in making connections by understanding the relations between critical choices in systems research design through separate, although intricately related, topics. By linking the elements of relevance, a stronger overall whole can be constructed. In this way, sound systems research can adopt fixed (and emergent) rules within flexible (and responsive) governing strategies (Koestler, 1969).

Timing: Release of Systems Conclusions

An additional consideration in systems reporting is the recognition that the systems being reported on will be operating in timeframes and cycles set by the system (Holling, 2001). While the mantra of "publish or perish" may create an environmental urgency, the system being investigated may not have process cycles that fit exactly or neatly within funding, project acquittal, or publication deadlines.

If systems research describes a particular system cycle, the researcher must be circumspect about reporting on systemic outcomes, definitive observations, or resulting impacts on any shorter timeframe (Ahl & Allen, 1996). This tension of making findings available in the "immediate now" has an impact on the validity of statements of the effect for "longer-now" life-cycles. Examples might include reporting on systems of ecological impact, modeling of probabilities of climate studies, longitudinal studies of health risks, or the lifetime effects of chronic stress and psychological change. The timing and content of systems research reports might actually depend on the system, not the career of the researcher.

Completeness: Adequacy for Systems Evaluation

Often the evaluation for systems research reporting follows prescribed criteria or will use a scoring rubric (C. Perry, 1998). A doctoral dissertation examiner will have specific criteria to report on. An academic journal will have a template for submission and criteria for the reviewer to use to confirm acceptance. Good research with distinctive qualitative merit, that fails to meet specific criteria, can fail to be communicated due to its incompleteness. Sometimes, ostensibly good research will be denied publication simply because of overlooked procedural criteria. For this reason, never forget to obtain the evaluation rubric prior to designing, completing, and submitting your (otherwise complete) research report.

For example, a respected systems research journal's editorial policy will require the reviewer to consider:

- Does the manuscript contain new and significant information?
- Is this new information sufficient to justify publication?
- Is the title, abstract, summary, tables, and article length sufficient?
- Is adequate reference made to other work in the field?
- Can any of the material be deleted without detriment?
- Does the work have originality, accuracy, and completeness?

Similarly, a doctoral dissertation committee may consider criteria like:

- Originality and scholarship;
- Contribution to knowledge;
- Independence of analysis;
- Criticality of thought;
- Situated relevance to wider discipline;
- Clarity and cogency (of argument, tables, and diagrams);
- Strengths and limitations (of scope and research design);
- Coherence of linkages (between method, analysis, and conclusions).

The significance of such criteria is that, while the research must be conducted impartially and independently, the reporting of research is situated within the context of the formal systems that enable new additions to human knowing. Those systems begin with the processes for evaluation, review, and publication and extend to how research enables and extends humanity's own understanding of the processes of its knowing. When we reflect on the primary contribution of valid research, the research itself is only one component. The wider system of researching also benefits each time a researcher adopts a sound system for their research (Kuhn, 1983). The participation in good research processes knowingly may itself be a benefit equal (or greater) to the actual research outcomes delivered. In this way, the research, the researcher, and research generally may each develop concurrently.

Suggestion

- Consider drawing of a schematic of the system diagram of your actual research design as a checklist for your own understanding of the five elements of "systemic" systems research (i.e., structure, boundary, relations, timing, completeness). If the elements do not come together as a logical proposition, reflect on the systemic weaknesses and the reasons for their presence. Seek guidance from other experienced researchers as to possible inclusions, modifications, or alternatives.

Choices in Reporting and Writing Up

A successful book is not made of what is in it, but what is left out of it.

– Mark Twain, *The wit and wisdom of Mark Twain*

From the suggestion to think about describing a systems research inquiry systemically comes the question of "Which elements, from the whole of the research, are to be selected for their significance?" The researcher will recognize that these choices affect the way in which the research is received. In this section, we will consider choices in meaning, paradigms, tone, and complexity. These are questions of emphasis common to the writing up of all research. The following discussion reveals the distinctive choices systems researchers need to make and why these are specific to systems research.

Choice of Meaning: Systems Concepts and Conventions

A difficulty facing systems researchers is how to use systems terms consistently. This concern also applies to those researchers introducing systems concepts into other disciplines. The use of unspecified and ill-defined *systems-like language* is a constant source of ambiguity in the communication of systems research findings. In communicating across paradigms, and in multi-disciplinary contexts, often the different reading audiences will maintain a very different systems lexicon.

Even within the systems discipline, different schools, and paradigms use similarly defined concepts as "terms of art." These terms, when used accurately, will have context specific and historical meanings (e.g., system dynamics, systems thinking, systems models, systemic interventions; Ramage & Shipp, 2009). The disciplines that inherently involve elements of systemic design (e.g., architecture, organizational management, software engineering, urban planning) also adopt terms resembling systems concepts for ideas involving distinctly different meanings (e.g., structure, function, form, open, closed, order, flow, etc.). Familiar systems terms may have a common usage, a formal systems definition, and a discipline-specific technical meaning (see Table 6.1). In reporting your systems research you must distinguish between these terms consistently and expertly.

Table 6.1 Common systems research terminology (and homonyms)

Defined term	Common meaning	Systems meaning	Technical meaning
Holistic	An entire thing (e.g., all parts together)	A distinct philosophy (e.g., holism vs. atomism)	The field of healthcare (e.g., holistic medicine)
Feedback	The giving of advice (e.g., positive customer appraisal)	A cybernetic information loop (e.g., positive feedback loop)	Any compounding noise error (e.g., data filtering)
Complexity	A difficult problem (e.g., business management)	The field which examines hierarchical integration (e.g., complexity theory),	The engineering of complexes (e.g., computational engineering)
Emergence	The appearance of newness (e.g., entering industry player)	A pattern in dynamic complexity (e.g., the emergent property)	The event of biological evolution (e.g., emergence of life)

(continued)

Table 6.1 (continued)

Defined term	Common meaning	Systems meaning	Technical meaning
Sub-system	A smaller part (e.g., a separate sequence in a manual)	A component in systems hierarchy (e.g., sublimated orders of complexity),	A specific component in an engineering schematic (e.g., an electronic sub-routine)
Network	A related group of people (e.g., a business network),	A set of systemic relations (e.g., networked food-chains)	Some formalized structural linkages (e.g., electricity transmission grid)
Structure	A construction project (e.g., an incomplete building)	The composition of a mapped system (e.g., relations of system parts)	An aesthetic totality (e.g., the architectural form)
Model	A small-scale replica (e.g., a model of the prototype)	The replication of systemic patterns (e.g., causal loop run-times)	The experimental manipulation of parameters (e.g., testing aerodynamics)
Dynamics	The tensions between people (e.g., sources of conflict)	The variables in a system (e.g., parameters for alteration)	The range of performance (e.g., the metrics of engine outputs)
Order	The sequence of events (e.g., the ordering of steps)	The arrangement of components (e.g., concatenation of relations)	The aesthetics of complexity (e.g., the transition from order to chaos)

These few examples highlight the precision of description required in systems reporting. When writing up systems research it is worthwhile to be aware that a term familiar to you (and your peers) will have a very different meaning and conceptual foundation when read outside of your discipline (or peer group). The use of an ambiguous term for a precise systems concept in formal system theory (e.g., hierarchy, resilience, tolerance, boundary) will be clearly apparent to a systems-literate reader.

Suggestion

- Use a glossary of systems terms during your write-up to confirm your accurate use of each systems concept, and provide a text-specific glossary if these terms will differ in use from their formal (or common) meanings.

Choice of Paradigms: Schools, Methods, and Models

It is useful to a novice reader of systems research if they can quickly locate your unique research topic within the wider landscape of academic research. When engaging in multidisciplinary research, or multi-method research processes, such delineations may seem artificial. However, to be read and received well, the community of discourse for whom the research is most recognizable and relevant, should be named. This step of naming the primary paradigm guides not only adherence to existing standards of discourse, it also helps with locating which journals, publication formats, and reviewers will most value the research and respect its integrity.

The classification of academic disciplines is itself a complex system of discrete, yet interconnected, boundary delineations (Del Favero, 2003). The identification of a commonly accepted list of departments, faculties, disciplines and fields involves consideration of paradigm maturity, pragmatic application, and system focus (Biglan, 1973). To assist you in locating your own research, consider the following delineations as a generic guide (see Table 6.2).

Table 6.2 Delineations of research fields, paradigms, and schools

Category	Common definition
Field	An area of study in science or research
Discipline	A branch of formal learning or inquiry
Paradigm	A set of exemplar practices or processes
School	A group of like-minded people in study
Methodology	A scientific method of applied research
Method	A systematic procedure in formal use
Modality	A particular approach, technique, or process
Locality	A geographic region or business association
Sponsor	A person or group supporting a broadcast
Profession	A group of people in a calling or vocation

The acceptance of a researcher's chosen form of research design will benefit greatly from the matching of the research question and the chosen approach to the paradigm of its formal reporting. Knowing where to situate your own unique approach to a systems research question will ensure there is a receptive location for your research contribution. The suggestion to those choosing to navigate by intuitive "way-finding" in the oceanic currents of new knowledge is that is worthwhile to also locate the islands and safe-havens in the embodied paradigms of our knowings (Maturana & Varela, 1987).

Suggestion

- The simple reflective practice of inserting a one-line description of how (or where) your research is located within each of the levels of a field will provide you with your research identity and focus. In choosing to locate within a paradigm, research group, formalized modality or defined locality one can still innovate, while noting the limitations and providing new developments, from within a sound theoretical foundation.

Choice of Tone: Voice, Tense, and Stance

The concepts of voice, tense, and stance are often confusing for early-career researchers. For clarity, these can be defined as:

- *Voice:* the syntax of a sentence emphasizing either the subject or object of the topic discussed (e.g., active, passive).
- *Tense:* the time of occurrence in terms of the description of what is happening, did happen, or is intended to happen (e.g., past, present, future).
- *Stance*: the location of the researcher in relation to the system indicated by their reporting perspective (e.g., participant, commentator, observer).

In generic writing education a trend has been to promote use of the "active voice" where possible. The active voice is seen to be concise, clear, direct, bold, vigorous and convincing (Strunk, 1918). This is an important skill to learn for early writers. It helps to develop their opinions and gain a level of confidence in self-expression. In systems reporting the blind use of active voice has the distinct problem of confusing objective observation with narrative opinion. In stating clearly "how things are" it is difficult to evaluate how this may be different to unsupported statements of "how things appear to me." In reporting on systems research, the active voice can be actively misleading.

To be intimate enough to astutely describe (and notice changes in) a system, requires the systems researcher to become an active participant in the "system of that system" (Reason, 1994, 1999). To report on this objectively requires the system to report on the system of reporting, as a form of second order cybernetic feedback (von Foerster, 2003). The additional act of describing or depicting the system as a commentator of system dynamics makes the researcher a biographer (or portrait artist) in representing what they are seeing. The effect on the seen, of the seeing, and its showing, is not ignored in mature systems research methods (Maturana, 1988). This awareness is reflected in the precision of the combination of choices of voice, tense, and stance that a systems research author adopts.

However, in systems observation and research, there is often no easily apparent "agent" to whom we can attribute the primary focus (Whyte, 1991). In the evaluation of systems research, use of the active reporting voice can make every declaratory statement of fact objectionable, if it is unverifiable (i.e., as opinion, not observation). Similarly, the default adoption of a passive voice to provide the illusion of distance (e.g., reporting on one's own community's learning) will provide only an appearance of impartiality from within a systemic intimacy (Maturana & Bunnell, 1999).

The question of research validity is actually determined by voicing accuracy. The ability to select a reporting voice appropriately is a mature research skill that applies beyond mere clarity of expression. Researchers must be cognizant of their "stance" relative to the system itself, if they are to make valid statements from an identifiable perspective.

For example, consider these sample sentences (as examples of combinations of voice, tense, and stance):

- The unsustainability of the recycling system is clear to all [active].
- The recycling system has been shown to be unsustainable [passive].
- The recycling system's unsustainability was due to its design [past].
- The unsustainability of the recycling system now becomes clear [present].
- The system will become unsustainable by the fact of its design [future].
- As designers, the recycling system fails our own criteria [participant].
- The recycling system's failure is its unsustainable design [commentator].
- The criteria for system sustainability were not met [observer].

We may have a preference for the voice that feels best to us. The correct form is the one that best describes the type of research completed. The actual choice of voice is determined by the research form used and the location adopted for the researcher's chosen perspective.

Suggestion

- Be mindful of the choices of voice when reporting systems research. Generally, one voice suggests one audience, one research role, and one primary perspective. A combination of voices may be required to accurately describe different stages, levels of involvement, and the perspectives taken during the research process. If mixing voices, signal each change in the report by using different sections and use that voice consistently throughout that section.

Choice of Complexity: Ontology, Hierarchy, and Humility

Often researchers are perplexed at the starkness of the contrast between how two peer-reviewers will perceive the same piece of research. While each may see obvious deficiencies and errors similarly, the reactions to the research can appear to be coming from completely different landscapes of experience. Using a systems understanding—of the understanding of systems—means your intuitive recognition of the difference in systems of perceptions is accurate. Not all systems researchers are seeing the same system similarly (Fischer, 1980). The communication of systems understandings can become like the appreciation of abstract art. The clarity of representation is partially seen in the eyes of the beholder (Gebser, 1985). For this reason there are technical difficulties specific to the communication of systems research and its abstract ideas (Dombrowski, 2000).

We can recognize from developmental psychology studies that adult cognitive development is not a homogeneous landscape of one universal type of thinking (W. G. Perry, 1999). The ways adults organize experience (i.e., post-formal operational thought) does not support the assumption of a single uniform psychological system (Commons & Richards, 2003; Dawson-Tunik, Commons, Wilson, & Fischer, 2005). Independent of variations in intelligence, personality traits, and past personal experiences, the differences in operant systems of cognitive complexity means researchers will organize systems observations quite differently (Fischer, Hand, & Russell, 1984). For the researcher, this means that one audience is made of many minds. Two implications follow from this appreciation of audience diversity. The first is, not everyone is seeing what you are seeing. The second is, not everything you are seeing can be shown. In the communication of systems research this raises the question of choice in "ontological appropriateness" (Varey, 2014).

While characterizations of the same system by different researchers may be idiosyncratic to each researcher, the reason that systems descriptions can be communicated meaningfully at all is found in the premise that there are common features in the formation of adult abstract thought (Buckle Henning & Chen, 2012; Marton, 1981; Torbert, 1994). Actually, much can be known about how adults form abstract concepts (as is routinely done in the systems research field) from the research into developmental action-logics and the skill in forming abstractions in systemic reasoning (Cook-Greuter, 2000; Fischer, 1980). Informed by integrations in these research fields we can actively ask: How might systems thinkers knowingly organize their form of system thinking?

Knowing something about the systems of adult human thought will allow you to organize your research to communicate to different systems audiences appropriately. The question of how to "pitch" the complexity of your research will determine if your reporting accurately hits or completely misses its intended mark. To demonstrate this idea that the landscape of thought has discernible features and in-common categories, we can compare three hierarchies of developmental logics necessarily used in systems research (Floyd, 2008; Graves, 1970; Varey, 2007). These comprise existential motivations, self-other relations, and complexity of systems perceptions. Essentially, these are the "why look," "towards what," and "seen how" comprising the systemic logics of common forms of systems conceptions (see Table 6.3).

Table 6.3 Levels of abstractive systems logics

System motivation	Systemic relations	Systems perception
Ontonomistic	Reflective	Potentialist
Extensionalistic	Enactive	Synthesist
Experientialistic	Evocative	Dialectalist
Structuralistic	Descriptive	Contextualist
Relativistic	Representative	Constructivist
Multiplistic	Comparative	Organicist
Absolutistic	Collective	Structuralist
Objectivistic	Conative	Mechanicist
Ritualistic	Symbolic	Staticist
Autistic	Sensate	Automaticist

Adapted from "Ontological appropriateness: Relevance, significance, importance," by W. Varey, 2014, *Aspects of Apithology: The Journal of Apithological Practice*, *5*(2), 1–11. Reprinted with permission.

We appreciate from this broader landscape that different research motivations, for different systemic relationships, using different complexities of perception generate distinctly different systemic conceptions (Varey, 2012). Each conception relies on different ordering principles, altering the interpretations of distinctive levels of complexity. As a result each has a different ontology for their system of perceiving. The perceived reality (as it presents itself) is constructed differently, having different content available cognitively (Torbert, 1999). When communicating between orders of complexity, or making large jumps across levels of meaning, the impact felt is the problem of misconception. This often results in an unbridgeable chasm of lost meaning and unresolvable academic conflicts. The effect of a disjuncture between conception and perception is evidenced by the three most common problems in communicating systems thinking. These can be explained very simply as:

- *Conflation:* If one cognitive system extracts limited detail from a higher-order complex system selectively, while reducing the boundary of inclusion (e.g., "*this is essentially the same as X"*).
- *Abstraction*: If one cognitive system extracts limited detail from a lower-order complex system incompletely, while extending the boundary of inclusion (e.g., "*only Y is really significant*").
- *Reduction*: If one cognitive system extracts limited detail from a higher-order complex system specifically, while maintaining the boundary of inclusion (e.g., "*its all actually caused by Z*").

We can recognize that we will naturally re-frame complex information in ways meaningful to ourselves individually. Each systems conception engages in sense-making in different ways and represents complexity differently. From this understanding, when communicating abstract ideas the *informed* researcher will first appreciate their own system of systemic perceiving. The more *aware* researcher will also understand how others will recognize or misperceive the chosen framing. The *astute* researcher will actually select the systems ontology that meets the complexity of the system being researched. The *mature* researcher will use all of these skills to communicate the system perceived within the many systems of perceiving. The appropriateness of the choice of ontological complexity enables the remarkable to be described unremarkably. Not appreciating the impact of this choice may mean your research will vanish inconsequentially. The aim is not to make the obscure simple for all, it is to make the obscured clearly apparent, to those who care enough to ask and to know well.

Suggestion

- In systems research, care must be taken that the information you are making sense of differently is not a conflation, abstraction, or reduction of an existing and understood system of thought. The ideal aim of a systems research discipline is to develop the skills of the researcher to see systems with clarity and discernment. Reducing the necessary complexity to greater simplicity runs the risk of solipsism, where the system described is only apparent to one person—being the researcher personally. Being aware of the landscape of the many possible systems conceptions allows for our own humility in not depicting a specific ontological framing as the only possible interpretation and valid systemic reality.

Common Errors of Omission in Systems Reporting

> Between us, we cover all knowledge; he knows all that can be known, and I know the rest.
>
> – Mark Twain (on meeting Rudyard Kipling), *The wit and wisdom of Mark Twain*

Your ability to meet the necessary, sufficient, and elegant standards of systems research will depend on the good choices you made at the time the research is formulated, conducted, and captured (see Chapters 3 and 5). The subsequent evaluation of that research depends on it being accurately reported (see Chapter 8). The reviewers of systems research can only evaluate what has been spoken to directly. In the absence of clear information, questions about the basis for an assumption, the categories of exclusion, or the actual actions taken may have to be asked. While aiming to omit information in the interest of brevity, it is also a courtesy to be comprehensive and transparent in describing all necessary information and steps undertaken. It is reasonable for a reviewer to assume that information omitted is in actuality nonexistent. It is therefore worthwhile to consider the obvious errors and omissions in systems research reporting that detract from otherwise excellent research.

Using the structure of this book as a guide, there are familiar and easily identifiable systems research reporting errors (see Table 6.4). These common “errors of omission” are easily seen by the experienced reviewer. These will not necessarily be errors in the research itself, only omissions from the reporting process. Seeing these omissions specified (and named for easy recognition) may prompt you to check if (and how) your reporting speaks to each consideration. Any obvious omissions are then easily avoided in the writing up and reporting process.

Table 6.4 Common "Errors of Omission" for system researchers

Lineage overlooking (see Chapter 1)	Has the researcher used terms and concepts that have a long history of development correctly, referencing both historical and contemporary understandings, and explained the origins of any beliefs relied on—or used undefined terms ambiguously, relied on discredited or out-dated historical perspectives, and put forward an unsubstantiated view at odds with the consensus viewpoints?
Framework forcing (see Chapter 2)	Has the researcher said why they chose the framework selected, explained its choice compared to valid alternatives, and what the choice privileges attention to and also hides from the research—or did the selection of the framework precede the research question, without demonstrating a consideration of other options, and with no noted appreciation of its inherent limitations?
Answer proposing (see Chapter 3)	Has the researcher succinctly stated the research question, explained the context and situation, and outlined the research design process—or has the problem definition pre-supposed the given answer, without reference to the governing context, and no systematic approach to the actual process of the research?
Movable modeling (see Chapter 4)	Has the researcher explained the parts of the model, the boundaries of inclusion, the relations between the components, and the range of outcomes possible so as to consistently produce the outcomes expected—or are the model parameters, assumptions, operations, and predictions a depiction of a wishful thinking, justified only by a diagram that is too flexible to be reliable or useful?
Dynamics glass-casing (see Chapter 5)	Has the researcher explained the framework, method, and application (FMA), selected an appropriate form of intervention, and demonstrated the effects of their actions—or not adequately distinguished method and methodology, with no set process of recording variations, and offered no prospect for intervention?
Template replicating (see Chapter 6)	Has the researcher explained all the steps intended, the sequence of actions taken, and honestly reported strengths and weaknesses—or filled in generic descriptions of an often repeated or modeled process, without evidence of the actual research choices, and no reflections on the insights gathered?
Endpoint announcing (see Chapter 7)	Has the researcher demonstrated the skills for the system of research relied on, evidenced practice proficiency, and shown clear understandings with humility—or is the researcher confused about basic concepts, has failed to draw important distinctions, and neglected the next stages of investigation with no expectation of continuation?
Uncritical adopting (see Chapter 8)	Has the researcher put forward a credible (or even novel) contribution to systems knowledge, correctly applied systems ideas systematically, and thought about their research systemically—or adopted a systems narrative as a convenience (or contrivance), that does not assist the discipline, the research, or (ultimately) the researcher professionally?

If critical steps were not included in the research process, they are not recoverable at the reporting stage. Instead, the effective remedy is actually the preventative action of using this book as a guide. The choices made for *good* systems research design (set out in the other chapters of this book) will enhance the decision-making skill of each researcher. This is the best way of avoiding these errors of omission entirely. Finding an experienced person to guide you through these choices will facilitate the development of your own research judgment, discernment, and authentic engagement.

Some practical suggestions for early systems researchers to directly meet (or even prevent) each of these common errors, include:

- Lineage overlooking—in taking space and time to define the system, do not also neglect to situate the research in a relevant practical and historical context;
- Framework forcing—in adopting a framework, model, or systems heuristic, reference its originating concept (at source) and any deviations from this;
- Answer proposing—introduce the systems premise and its reasons early, so that the appearance of a system diagram in the conclusions is not unexpected;
- Moveable modeling—describing systems models in words is tedious, consider instead commissioning professional technical design and systems artwork to communicate the changing dynamics accurately;
- Dynamics glass-casing—a great benefit of a systems analysis is the possibility for systemic enhancement; therefore, in describing any dysfunction consider speculations (or specifications) for the system's enrichment;
- Template replicating—because different modalities have different reporting flexibilities, some newer fields willingly permit novel reporting conventions;
- Endpoint announcing—incorporate key systems concepts into the defining character of the research, using these knowingly and provisionally, as the primary (and iterative) focus for embodied systemic discovery;
- Uncritical adopting—when adopting a systems idea as a metaphor, isomorph, paramorph, or analogy, ensure the thinking behind the premise is shown transparently to evidence its relevance, appropriateness, and effective use.

Primarily, the objective of systems research reporting is to ensure the systems discourse is enhanced and the researchers themselves are encouraged. It is helpful for you to know what systems reviewers will look for in meeting these joint aims.

Ethical Considerations in Systems Reporting

> Education consists mainly in what we have unlearned.
>
> –Mark Twain, *The wit and wisdom of Mark Twain*

Systems Research Ethics

The systems research community commonly refers to its own discipline as the "systems sciences" (Flood & Carson, 2013; Klir, 2013). The research standards for scientific inquiry can be sensibly applied to systems research reporting. The National Academy of Sciences (2009) publishes a guide to scientific researchers on ethical values, scientific standards, scientific misconduct, and questionable research practices. The scientific standards for research generally poses the question: Are there other research and reporting ethics unique to the systems sciences?

To commence the consideration of this question we can propose three ethics specific to systems research and its reporting. These concern three features of the systems discipline, being boundary delineation, component identification, and framework abstraction. These elements logically form the three ethical risks of marginalization, universalization, and excision. A brief explanation (with a canon of conduct) is provided for each:

- *Risk of Marginalization:* The formation of a system inquiry loses relevance at its natural or explicit boundary of inclusive efficacy. In doing participatory consultation, those participating are sometimes assumed to be systemically representative, even if only of those who are the sole participants. The utility of a system investigation is constrained by its degree of separation from its strong and weak bonded external associations (Midgley, 2000). The solution is not to form ever-greater inclusions; rather, it is to accept for each study its specificity of non-inclusion.

  Canon #1: Necessary non-inclusions may be practical, political, pragmatic, or personal, and being ever present are always noticeable.

- *Risks of Universalization:* In identifying the components of a system, whether empirically, socially, or philosophically, there is a process of determining significance and insignificance. What is significant might be determined for a specific context by elements of culture, history, interdependences, and personal relevance. In identifying the *ideal* system these contextual inclusions may be generalized. The ethical risk for systems research is the universalization of findings from one specific instance to all conceivable locations (von Foerster, 2003). Although a systemic understanding from one context will rarely work in another without adjustment, simplified forms of generic applications make invisible the negation of local elements of importance. The solution is to replicate the integrity of the original systems inquiry to discern the inductive differences that are context specific.

  Canon #2: A generic universal framework hides as much as it discloses.

- *Risk of Excision*: The power of an accurate systems description is found in its capacity to provide a representation of the abstractive separated from the specific. The explanatory benefit of a precisely refined abstraction is how it holds the whole, while omitting almost all the detail. This is distinguished from the act of "precision" (from the Latin, "to cut") where the abstract representation excises parts only for convenient examination (Peirce, 1957). When abstraction escapes from the necessary complexity, rather than representing it, the purpose of the systemic inquiry is lost completely. The solution is to ensure that all parts are represented in the new level of depiction.

Canon #3: Ensure details of significance are not ever negated, simply to fit our containers of contrived elegance.

Suggestion

- To think about the systems discipline as a science lends itself to being considered as such. Rather than convenient explanations, consider the rigor required to put forward independently verifiable observations and knowledgeable convictions. To support credibility, consider always the implication of later reliance, in making false claims of reliability.

Systems Research Heuristics

The act of describing a system, whether in an empirical model, rich picture, or simplified diagram, produces a representation. The production of systems artifacts involves a conscious choice of selection. In forming a system heuristic *some* of the relations, between *some* of the parts, representing *one* whole part (of a larger whole) are abstracted. This is designated (either verbally, diagrammatically, mathematically, or virtually) *as the system*. We recognize these systems diagrams as only ever being an approximation; merely a map, metaphor, or metonym. They represent part of the terrain of a more nuanced fuller reality. The cautionary adage, *the map is not the territory*, is often used as a precautionary qualification. However, the case must always be made for the relevance, accuracy, and sufficiency of our systems depictions.

Korzybski (1933), when outlining a formative version of the *Theory of General Semantics*, used the figurative metaphor of maps, specifically a metaphorical map to get from Paris to Warsaw via Dresden, to represent the structure of his complex abstract semantic argument (about semantics). To do this, he outlined four interrelated maxims, which read:

A. A map may have a structure similar or dissimilar to the structure of the territory.
B. Two similar structures have similar 'logical' characteristics…
C. A map is *not* the territory.
D. An ideal map would contain the map of the map, the map of the map of the map, endlessly. (Korzybski, 1933, pp. 750–751)

As Korzybski (1933) explained within this original essay, the problem is not really with maps; these are very useful. The problem is when the second criterion is forgotten, being the matching of the logical characteristics of similar structures. This makes our maps (and metaphors) potentially unreliable. Korzybski (1933) warned that a map that becomes disconnected *in structure* from the underlying territory is in fact so "bad" as to be "misguiding, wasteful of effort" (p. 750) and in emergencies "might be seriously harmful" (p. 750). It is an irony that Korzybski's common quotation is itself an excision from the underlying structure from which it is taken.

Systems heuristics, especially those derived by vigorous and thorough investigation, contain great explanatory power. Their speed of adoption is often only outpaced by the compelling polemic of their persuasion. Whether climate models of sea-level rise, descriptions of ecological process, or systems diagrams of knowledge frameworks, our simplified depictions become the basis for decisions. Those decisions can have inter-generational impacts and far reaching effects. Consequently, much harm can arise from the adoption of simplistic mental models taken from the maps of false structures.

There is for each systems researcher an applied *ethic of representation*. The desire to create and provide a system heuristic as an easy explanation must not persuade you to distort the complex relations of the territory represented. The ethical standard required is not only to routinely warn of the qualified use of the unreliable map offered, but not to be the originator of a distorted topography (that can be used badly). By holding this precaution closely, each systems researcher may advance the ethic to preserve and enhance the landscapes of informed and reliable thought.

Suggestion

- Recognize the heuristic created to represent your research will be lifted from its context. Incorporate links to source, structure, territory, qualifications and timeframes so that the narrative adopted by others (and attributed to you as source) is not one to be later regretted.

Reflections and Summary

These reflections on the distinctive features of reporting systems research speak to what makes systems research so interesting. While systems research is mostly about having a set of paradigms, processes, and frameworks to follow, it is also a mindset to be cultivated. This mindset communicates an appreciation for what is easily seen partially, but is rarely seen in integrated ways, differently and uncommonly. Through our systemic inquiries we reveal aspects of the world unseen. In reporting these using a systems mindset, we embody the thoughts we are communicating. The great benefit of reporting our systems research well is that our research gets to be seen, and we are able to see ourselves revealed, equally.

While fragmented, disjointed, and incomplete research raises questions of coherence and introduces doubt, elegantly done systemic systems research has its own aesthetic and reliability. As a systems researcher you are encouraged to do your research accurately. From this basis, you may also learn to communicate your own embodied expression of systems research competencies with confidence and personal clarity.

The advancement of science is often described as being about new discovery (Kuhn, 1974). The more recent recognition is the advancement of normal science mostly concerns the ability to follow routine methods consistently. Great advancements in research necessarily involve new horizons of perception and novel paradigms of investigation (Kuhn, 1983). A systems research approach potentially provides new understandings about the limits of our paradigms and systems of research routinely adopted. For each new vista of seeing, a researcher may have to develop their own rigor, in which they might be the first pioneer.

To encourage others to follow our own successful research examples, it is best not to announce early work as an endpoint conclusion, but instead, provide a path, bridge, and ladder into the new territories that others can investigate. Having a personal level of knowledge humility means our collective research endeavors will continue indefinitely. In announcing your findings, be bold, but not boastful; creative, but not careless; innovative, but not ignorant; and contributive, but not conceited. In this way, reporting your knowing astutely will benefit the system of humanity.

Based on this summary checklist, you will have done well in the role of systems researcher when in your research reporting you have:

- Taken a systemic approach to the design, recording, and reporting;
- Considered the location of your research in the *system of research*;
- Explained the system of research concordance by aligning five elements;
- Limited any validity claims to the boundary of the systemic inquiry;
- Followed a schematic for completeness of all necessary pre-requisites;
- Adopted a clear approach to choices of composition, tone, and balance;
- Taken into account ethical, professional and aesthetic considerations; and
- Provided a facilitative platform for favorable evaluation of the research.

In following each of these elements, you may have possibly communicated your completed research, so it can be seen as: *descriptive, situated, concordant, selective, sufficient, distinctive, authentic*, and *transparent*.

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Chapter 7
Competencies Necessary for Systems Research

Pamela Buckle Henning

Abstract Conducting systems research requires both knowledge and competence. This chapter outlines key perceptual competencies demanded of systems researchers. We begin with the ability to perceive the presence of systemic wholes and parts. Next, we consider competencies involved in perceiving key characteristics of complex systems (order, change, relationships, and information). Scholars are often called to generalize their findings to other settings; the search for similarity among different contexts involves analogical reasoning, an important perceptual competency for skillful systems research. We address challenges of engaging with the uncertainties of systemic inquiries, along with a call for systems researchers to be reflexive of the ways they become personally affected by the phenomena they investigate.

Keywords Systems research competencies • Perceptual competencies • Complexity • Analogical reasoning • Uncertainty • Reflexivity

> Teaching a way of thinking is harder than teaching substantive factual material.
>
> (Checkland, 1999, p. A42)

Introduction

This guide has described how systems researchers must account for the philosophical underpinnings of their inquiry, how a systems framework can inform research work, and how to design research that is both systemic and systematic. We have discussed how modeling can be used in systems research, how researchers take action to conduct a study in effective ways, and how to communicate the outcomes of systems research. All of these are important stages systems researchers must move through in the course of a research project. This chapter does not address a specific stage in the systems research process. Rather, it focuses on competencies a systems researcher must possess in order to embark on systems research at all. We

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M.C. Edson et al. (eds.), *A Guide to Systems Research*, Translational Systems Sciences 10, DOI 10.1007/978-981-10-0263-2_7

consider the competencies described here to be foundational—necessary regardless of one's favored systems tradition or methodology: systems dynamics or cybernetics, critical systems heuristics or systems engineering, soft systems methodology or inquiry into complex adaptive systems. Abundant research on each of these approaches to systems inquiry has addressed skills particular to each. In this chapter, we seek instead to identify competencies required of any individual who wishes to conduct research about a systemic phenomenon, regardless of the systems traditions or methods that inform that research. While the literature on competencies often stresses behavioral techniques to be mastered and action steps to be taken in a given situation, we will focus here on perceptual competencies—cognitive and affective abilities we consider crucial in order to perceive systems and navigate the challenges of conducting rigorous systems research.

Knowledge about systemic phenomena is important, given the complexity of the gravest problems and greatest challenges we face in the twenty-first century. Systems researchers play an important role in meeting those problems and challenges. Over time, a large body of knowledge has amassed enabling us to understand the ontological workings of a system. However, systems are not apparent to everyone. Perceiving a *system* amidst disparate people, behaviors, objects, and events spread over time and space is a considerable mental leap, one regularly taken by systems researchers. What competencies are required in order to do this? What competencies are required of those wanting to investigate systems in a rigorous way? To date, the cognitive competencies required for perceiving systemic interconnectedness, the affective competencies required for skilled decision-making when working with systemic phenomena—are largely unknown. Our intention in this chapter is to suggest key perceptual competencies necessary to do systems research.

Competency in Perceiving the Qualities of Parts and Wholes

> Measurement is not all there is to scientific activity.
>
> (Morin, 2015, p. 237)

Since its beginnings as a school of scholarly thought, systems theorists have taken a stand against reductionism as the only philosophical stance fruitful for scientific inquiry. As a governing logic for science, reductionism informed generations of researchers to divide complex phenomena into parts, and to categorize and measure them. It has guided us to understand large, complicated entities by searching for simpler, basic entities within them. However, its success as *a* governing logic has come to mean reductionism is seen as *the* legitimate way people should utilize their minds to conduct research. It has come to mean that scientific inquiry ought to focus primarily on certain qualities of a phenomenon—"the quantifiable and the mathematizeable" (Goodwin, 1999)—deeming the non-measurable qualities of phenomena that exist in our world less significant. Science has evolved to handle "primary" (i.e., measurable) phenomena fairly efficiently. However, the phenomenal properties of experience (Tye, 2015)—the subjectively experienced qualities of life termed "qualia" (C. Lewis, 1929)—science considers "secondary" (Locke, 1995). Thus, commitment to reductive logic has impoverished our understanding of many interesting questions: What are the humanly experienced properties of climate change? Of individualism? Of information technologies? Of health? Of refugee crises? Of spiritual belief? The organizing scheme of science is a vantage point with distinct disadvantages.

Since Galileo, the methodology of science has emphasized the study of number and measure (Goodwin, 1999). To measure something, one must delineate it from other things. Thus, Western science has evolved as a pursuit of knowledge through "analytical consciousness, which emphasizes distinction, separation, and causality" (Bortoft, 1997, p. 91). Analytical consciousness is indispensable for quantitative reasoning. Analysis is oriented toward counting parts (which necessitates separating that which is to be counted). Thus, scientists become highly skilled at perceiving separateness. In its enthusiasm for measuring *quantities*, science tends to de-emphasize the skill involved in identifying the *qualities* of phenomena. In particular, the ability to perceive qualities of wholeness—the ways elements of a phenomenon belong together in relationship—gets obscured by analytical consciousness.

And yet, humans (scientists included) experience the non-separated ways the world operates every day—from traffic jams to the intricacies of workplace politics. Humans perceive the ways interconnected phenomena go together in wholes by a psychological process Carl Jung termed "intuition" (Jung, 1971). In a universe that involves both quantities and qualities, capacities for disciplined intuitive skill are as important as disciplined analytical skill. Since the eighteenth century, there have been scientists documenting rigorous and replicable research using non-analytic methods. At the core of these methods is a focus on discerning qualities of wholeness (thus, they are variously referred to as a "science of wholeness" (Bortoft, 1996), or a "science of qualities" (Albertazzi, 2015; Goodwin, 1999).

Suggestion: Consider the ways you approach your systems research work

- How do you "divide and conquer"? This illustrates the workings of your analytical consciousness.
- What do you find hard to "divide and conquer"? This hints at properties of inherent wholeness you may be intuiting that cannot be well understood via analysis.

Why should it be necessary for systems researchers to develop highly refined capacities to perceive qualities? To thoroughly describe the qualities of a thing you must describe its relationship to other things—that is, you must describe its qualities of relatedness. Relational qualities point to unifying structures, systemic ordering principles—that is, wholeness—exerting influence on parts in ways that are often obscured by the wide number and diversity of parts involved in complex phenomena.

It is not easy to discern qualities of systemic relatedness among parts, particularly when those relationships operate across large distances of space or time. Yet these qualities of relatedness are precisely the qualities that analytically oriented science often fails to understand, and precisely the unique contributions that systems researchers can make. It takes considerable skill to convincingly communicate a system's qualities of relatedness to others (Varey's Chapter 6 of this book is dedicated to this challenge). Laypeople and scholars alike are used to seeing the world as filled with fundamentally discrete objects, events, and ideas. For most people, parts seem fairly manageable, tangible; we experience wholes (aka *systems*) as more difficult, abstract, and somehow less *real* than the parts of which they are comprised. To the systems researcher, however, parts are interesting precisely *because* of their qualities of connection to larger systems: To the systems thinker, "A part is only a part according to the emergence of the whole which it serves!" (Bortoft, 1996, p. 11).

Suggestion: A thought experiment
Consider several data points you have collected that appear unrelated:

- Under what circumstances, by what ordering principle, would these seemingly unrelated data make perfect sense? In what ways might they be necessary indicators of a particular systemic wholeness, localized expressions of a greater wholeness you don't yet understand?
- Before discarding data as outliers, invest time in this thought experiment, assuming that the mere fact they occurred could indicate they express particular, significant qualities of a pattern of systemic wholeness.

At its most fundamental, systems thinking requires the ability to discern that objects, events, and ideas relate to one another in ways that create systems. We might frame this as *parts-driven systems thinking.* A subtler systems thinking skill is to discern how every part contains qualities of a wholeness of which it is a part. Consider what "wholeness" means according to the *Oxford English Dictionary*: "completeness, being in an unbroken or undamaged state." From the perspective of wholeness, the presence and behavior of parts are exactly necessary for the expression of that particular wholeness. We might frame this as *wholeness-driven systems thinking.* When we consider the deeply embedded systemic complexity of the universe—that every system is a part of many wholes—we must consider that every choice to alter a system is a choice to break or damage a particular expression of wholeness, completeness, which likely impacts multiple expressions of completeness far beyond what we can predict.

Suggestion: Consider a university where you have studied

- Parts-driven systems thinking: In what ways are its students, faculty, and staff necessary to the existence of that university?
- Wholeness-driven systems thinking: How does that university express its qualities through the experiences of the students, faculty, and staff that comprise it?

Implicit in a systemic worldview, the qualities of wholes and the qualities of parts each inform the other. This demands systems researchers to develop the ability to orient themselves to both, not privileging either, in a movement akin to the hermeneutic circle. Systems researchers must be competent in both parts-driven systems thinking and wholeness-driven systems thinking. Physicist and philosopher of science Henri Bortoft describes the parts–whole relationship:

> Parts are the place of the whole where it bodies forth into presence. The whole imparts itself; it is accomplished through the parts it fulfills.…[Wholeness] emerges simultaneously with the accumulation of the parts, not because it is the sum of the parts, but because it is imminent within them.
>
> This process tells us something fundamental about the whole.…If the whole becomes present within its parts, then a part is a place for the "presencing" of the whole. If a part is to be a place in which the whole can be present, it cannot be "any old thing." Rather, *a part is special and not accidental, since it must be such as to let the whole come into presence.* The speciality of the part is particularly important because it shows us the way to the whole.…The way to the whole is into and through the parts.
>
> The whole is…not to be encountered by stepping back to take an overview, for it is not over and above the parts, as if it were some superior, all-encompassing entity. The whole is to be encountered by stepping right into the parts.…There is dual movement: we move through the parts to enter into the whole which becomes present within the parts. When we understand, both movements come together. (Bortoft, 1996, pp. 11–12)

This passage hints at the intricate skill demanded of systems researchers seeking to understand the qualities of both parts and wholes. In a systemically structured universe, we seek to perceive the qualities of many diverse parts because they clarify the wholeness of the system in which those parts operate. At the same time, we take the position that the particular qualities of wholeness being expressed by any given system are necessarily and accurately expressed through the diversity of the parts that comprise it.

Fundamentally, systems researchers must possess competency in perceiving systems. We turn our attention now to competencies required to research systemic phenomena: competencies necessitated by complex systems, analogical reasoning, engaging with the unknown, and reflexivity.

Complexity-Driven Competencies

Often, the systems a systems researcher chooses to investigate are complex. Complexity itself demands much of researchers. Understanding a phenomenon as a system exhibiting characteristics of complexity means that one cannot rely on research strategies aimed at simplifying phenomena. Rapoport and Horvath (1959) agree:

> The parts being simpler, they are supposedly more amenable to understanding. The idea of analysis is to understand the working of the parts…the hope is that it is possible to "build up" the understanding of complexity by superimposing the workings of the various parts. (p. 87)

Complex systems elude comprehensive understanding by analytic attempts at superimposing. Neither can we assume that entities comprising a system are arranged randomly, lessening the confidence we can place on statistical probabilities (given that probability statistics work best when we can justify assumptions of randomness). With complex systems, we find ourselves in a middle ground between simplicity and chaos (Weaver, 1948). Well-regarded skills useful to other subjects of inquiry must take a less central role in complex systems research. Other competencies become paramount when one seeks to understand the "deep nature" of a complex system (Lewin, 2002). Here, we propose four: competencies in perceiving order, change, relationship, and information.

Competency in Perceiving Order

> We live in a universe that produces information, and we are grammatical creatures, right down to the forty-six chromosomes producing our biological essence.
>
> —Robin Wood*, Beyond "e": Creating an Intelligent World*

For many, the thrill of systems research is identifying order where others have not. Order involves a particular arrangement of entities—be they ideas or automobiles, galaxies or germ cells—configured in space and time in an identifiable pattern. Order is the grammar of a particular system. The search for order involves the search for occurrences of objects or events that happen with regularity, exhibiting some kind of invariance amidst seeming change, some kind of self-similarity at different levels of analysis. The arrangement of objects and events in complex systems often appears haphazard; systems research is a means by which we can identify how such apparent disarray may be ordered by relatively simple rules. Regularities may be rough; they may also be found to be quite precise (Mandelbrot, 1963). In complex systems, order is oftentimes highly intricate.

This intricacy can emerge in dynamics of self-organization, whereby local interactions give rise to behaviors coordinated at a large scale in a complex system. Self-organized order can be difficult to detect. It can involve behaviors that are steady, yet not repeating themselves precisely, thus making the pattern less obvious to detect. Systemic behaviors often combine a measure of predictability and chaos—as in cases where behavior in a system is unstable at the local level yet the system remains stable at the global level. It is unsurprising that the term "strange attractor" (Ruelle, 1971) was coined to describe some kinds of systemic self-organization!

Suggestion: Think about self-organization

- Some assume that self-organized dynamics, occurring as they do without intentional design, must reflect natural laws that are therefore optimal.
- Adam Smith's argument about the "invisible hand" of markets is an example. However, "there is nothing intrinsically 'good' about the outcomes of self-organization.…Self organizing processes happen. There is no intrinsic superior morality or 'best fit' that emerges from the process" (Boulton, Allen, & Bowman, 2015, p. 45).
- Self-organization is a dynamic that gives rise to generative social change and to pandemics, to climate change and to the birth of new galaxies. It is an amoral phenomenon.

The ability to perceive order grants a systems researcher the ability to perceive forces for homeostasis that have developed in a system over its life span. Complex systems have an array of mechanisms for self-regulating, for maintaining states of equilibrium. Sometimes, systemic order itself is the focus of the systems researcher's inquiry: evidenced in countless studies aimed at examining the nature of and conditions involved in ideas such as "balance" and "sustainability." Perceiving order allows one to perceive anomaly within a system, which may signal the weakening of one ordering principle and shifting of the system toward another (i.e., a destruction of an old order, as a system's behavior gives way to a new one). Complicating matters, some systems can only achieve order through some degree of instability, as in the case of complex adaptive systems (Allen, 1997), which must continually respond to both internal and external events in order to maintain themselves. This demands of the researcher an openness toward both stability and its absence in order to accurately perceive and report on both.

Competency in Perceiving Change

Sometimes, systemic change is the focus of the systems researcher's inquiry evidenced in countless studies aimed at examining the nature of and conditions involved in ideas such as "evolution," and "emergence." Complex systems are dynamic; they change. Change takes many forms and demands of a systems researcher the ability to perceive and describe qualities of movement—difference over time or across space. Studies with these aims can subtly pull the researcher into an aversive relationship with the system's homeostatic, self-regulatory behaviors. Our challenge is to objectively discern and report on the functions and effects of both stasis and flux.

The nature of change in complex systems research exerts certain demands not faced by other researchers. For example, we need subtlety in ascribing magnitude. Given the nonlinearity of complex systems, "there is not a direct and easily predictable linear relationship between an agent's actions and the consequences of that action" (Lissack, 2002, p. 22). For researchers of simple systems or nonsystemic phenomena, the demands to classify behavior as important or unimportant, significant or negligible, big or small are relatively uncomplicated. Nonlinearity as a systemic characteristic makes the demand to ascribe magnitude challenging for the systems researcher. "Big" is not necessarily powerful; "small" is not necessarily weak.

Perceiving change requires a researcher to discern between regularity and novelty. In a changing system, novel actors, actions, and ideas emerge, at times quickly, often unpredictably. Detecting them demands a systems researcher to have flexible and responsive sensemaking structures (Weick, 1993); otherwise, early indicators of change will be unintentionally filtered out of the researcher's perceptual field.

Competency in Perceiving Relationships

The etymology of the word *system* includes the idea of “things placed or set together” (Partridge, 2009). For this reason, a most rudimentary competency in systems research involves recognition of multiple *things* involved in a phenomenon, requiring a researcher to seek out and examine each of them in their own right. This competency is so foundational that for many people, the phrase “systems thinking” means just this: that by virtue of their pluralistic nature, systems have more than one *thing* with which we must contend.

Yet, alongside this rudimentary competency driven by pluralism, the work of systems research is to investigate the way things are “placed or set together.” An important competency for a systems researcher is the ability to perceive the particular placement of entities comprising the system under study, and the particular qualities of their togetherness. Put simply, a systems researcher must have the ability to perceive relationships. In a complex system, this is not straightforward. In any given system, parts may relate in highly coordinated ways, may overreact or underreact to one another, or relate not at all. The action one part produces may be minimal or extreme at different points in time. Much of the work of systems research involves exploring the particularities of relationship among parts of a system that one usually finds are densely interconnected in unexpected ways. Parts of a system can be related in ways characterized by mutuality or asymmetry. Entities within a system can behave in ways that are dependent or counter-dependent. The actions and reactions that occur among related elements of a system can be regular or can vary. In systems research, we generally assume that actions of one element of a complex system will have consequences for another.

The relatedness that characterizes complex systems demands particular perceptual skill of the systems researcher pertaining to the issue of independence. It may appear that certain parts of a system operate independently. If the system under investigation is a living or social system, such appearances are illusory; it is not possible for entities involved in living or social systems to be independent of others. However, independence is a coveted cultural value, particularly in Western nations (Hofstede, 1984). Systems researchers who ascribe positive meanings to independence may unintentionally search for it or interpret data in a way that assumes appearances of independence uncritically. A competency vital to the researcher of complex systems is the ability to investigate apparently independent entities for their relationships with other entities. Doing so opens the possibility of uncovering relationships that may be subtle, yet crucially important to understanding the functioning of the system.

Just as in complexity we cannot presume the action of one entity has no effects on others, likewise we cannot presume that the proximity of entities dictates the strength of attunement they have to each other. In much scholarly inquiry, outlier data can be safely discarded as measurement error, or as merely irrelevant. However, complex systems can exist across widely distributed space and time. It is not always the case that relationships among objects or events within a system are significant only if they occur with relative nearness. Complexity demands the systems researcher develop a different stance toward time: "In living systems, even very simple ones, the behaviour at a given time is partly determined by memory and partly by the anticipation of the future. In this sense the future contributes to the present" (Prigogine, 2001, p. 225).

Competency in Perceiving Information

Perceiving the material objects within a system is easy. Perceiving the information that flows among them, and among the system's past, present, and future, is not. Systems are communicative. They do many things with and to information: import it, attract it, create it, digest it, stockpile it, move it around. At times, they actively ignore it (Mendonça, Cardoso, & Caraça, 2015), suggesting that systems can have an immune system to certain information perceived as threatening. Given the dense interconnectivity within complex systems, information exchange is an important dynamic to systems. The way a system engages with information can affect its behavior in both productive and counterproductive ways. Unsurprising then, systems evolve complex signaling processes to communicate information. Given the survival at stake in relating to information well, signal detection can be crucial to a system's continuance (Snodgrass, 1972); failure to detect "weak signals" (Ansoff, 1975) can cause a system's demise.

Given the complexities of many systems, discerning the presence of information (crucial to being able to link causes with effects) can be challenging. Systems research is stimulus-intense work. Amidst those stimuli, we often perceive "incomplete, unstructured, and fragmented information" (Mendonça et al., 2015, pp. 6). The systems researcher generally cannot afford to focus solely on qualitatively obvious or quantitatively high levels of information exchange within a system (i.e., strong signals). Organizational researchers have noted that relationships among parties engaged in *weak* signaling can play potent roles connecting otherwise disconnected parts of a network and importing new variety where regions characterized by strong signaling do not (Granovetter, 1973). In effect, information exchange that is *weak* can be *strong* in its effects on the system's overall functioning. The challenge for systems researchers is to detect information and to ascribe accurate meaning to it. This is no small feat. Every researcher's training and life experience creates in cognitive-affective frameworks described (also called worldviews [Kant, 1790] or mental models [Craik, 1943]). Those frameworks are mixed blessings: the education enabling our interpretive capacities as systems researchers provides us with dominant thought patterns that prevent us from perceiving information that seems inconsistent with what we know. Mendonça et al. (2015) describe the situation:

> A crucial feature of weak signals is their "weird" character.…Their weirdness is related to a gap in the current dominant frameworks of thought; hence what they imply is difficult to articulate in the context of the established grid of knowledge parameters. (p. 6)

Weak signaling is not created only by the systems we study; it is created by the ways we have been trained to think.

Competency in Analogical Reasoning

> General system theory is not a search for vague and superficial analogies. Analogies as such are of little value…
>
> (von Bertalanffy, 1969, p. 33)

> Analogy is an indispensable and inevitable tool for scientific progress. I mean a special kind of similarity which is the similarity of structure, the similarity of form, a similarity of constellation between two sets of structures, two sets of particulars, that are manifestly very different but have structural parallels. It has to do with relation and interconnection.
>
> (Oppenheimer, 1956, p. 129)

Many systems researchers consider Ludwig von Bertalanffy a founding father of general systems theory, and have been greatly inspired by his goal of a general theory of systems that could unify knowledge across disciplines. Echoing him, many systems researchers argue that the work of identifying systemic isomorphies is not a matter of inventing analogies. Their concern is understandable. When an American president drew an analogy between Saddam Hussein and Adolf Hitler—an "indiscriminate inference," or "naïve analogy" (Hofstadter & Sander, 2013)—it galvanized widespread public support for what became a lengthy and destructive Persian Gulf conflict. A mode of reasoning that can lead nations to war is, understandably, one that could do much to discredit scholarly work.

Yet, what should we make of Robert Oppenheimer's claim that analogical reasoning is indispensable? Contemporary cognitive psychology supports his claim: "Analogy is 'the core of cognition'" (Gentner, Holyoak, & Kokinov, 2001, p. 2). Of particular significance to researchers, Gick and Holyoak (1983) said:

> To make the novel seem familiar by relating it to prior knowledge, make the familiar seem strange by viewing it from a new perspective—these are fundamental aspects of human intelligence that depend on the ability to reason by analogy. This ability is used to construct new scientific models, to design experiments, to solve new problems…to make predictions, [and] to construct arguments. (pp. 1–2)

Contemporary psychology should make it difficult for today's systems researchers to dismiss analogical reasoning as soundly as von Bertalanffy did.

Simply put, analogical reasoning is a way the human mind identifies commonalities between two or more situations. Humans take knowledge about one situation and transfer it to another through a process that involves two aspects:

1. Finding "one to one correspondences" (Gick & Holyoak, 1983, p. 2) between the objects in a familiar situation and the objects in a new one; and,
2. Finding correspondences in the way objects in the familiar situation are related, and identifying the relationships among objects in the unfamiliar one.

Thus, analogical reasoning "is a process of aligning object representations and relational structures" (Dietrich, 2010, p. 335) from one situation to another. When we reason by analogy in systems research, we search for (a) similar objects in more than one system that are (b) relating in similar ways.

Importantly, when reasoning analogically, the search for correspondences is often incomplete. This does not signal the failure of the thinking process; rather, it signals the systems researcher to identify the nature of the differences, find ways to extend one's initial mapping assumptions, isolate key distinguishing principles, search for additional information about what was initially less well understood, to create additional knowledge. Thus, important contributions to knowledge can be made when a researcher identifies insightful analogies *and* when a researcher identifies un-useful disanalogies (Oppenheimer, 1956).

Any mode of reasoning that helps one focus on "relational commonalities independently of the objects in which those relations are embedded" (Prieditis, 1988, p. 64) has much to offer the scholar seeking to extend general systems theory whose central aim is to identify universal characteristics and principles governing all types of systems in all fields of study. Analogical reasoning involves discovering forms of relationship that are independent of context (Barsalou, 1982). True, not all systems researchers aim to further general systems theory. Analogical reasoning is, nonetheless, a useful cognitive tool. If used well, analogical reasoning can assist one in going beyond surface features of a system to detect commonalities in the relational structures at work in that system, and the dynamics known to operate in other systemic phenomena.

Suggestion: Two stances on context in systems research

- Focusing on context-dependence is crucial: when you are seeking to understand the boundary characteristics of an open system, or the information/energy flows between the system and the environment in which it's embedded.
- Focusing on context-independence is crucial: when you are seeking to identify common ordering principles operating in seemingly different systems or isomorphic patterns across disciplines.

Let us highlight characteristics of sound analogical reasoning: First, mapping objects between two or more systems (or parts of a single system) is good. Mapping commonalities in the ways those objects relate among themselves is better. In analogical reasoning,

> the one-to-one mapping principle states that each element in a base domain can be mapped to at most one element in the corresponding target domain. The systematicity constraint requires that, all else being equal, correspondences between systems of elements in the domains are preferred to matches between isolated elements. (Dietrich, 2010, p. 335)

In the psychological literature, this cognitive reasoning has a great deal to do with how one responds to the unknowns that an analogy reveals. A good analogy reveals what differing situations or systems have in common, and as importantly, points to further inferences that can be made about what their differences can teach us (Gentner & Colhoun, 2010). This is invaluable for scholarly research: "The lack of deductive certainty in analogical reasoning…means that analogy can suggest genuinely new hypotheses, whose truth could not be deduced from current knowledge" (Gentner, 2015, p. 108).

Suggestion: Consider analogical reasoning – the peril and the promise

- Peril: Beware of enthusiastically identifying "pure matches," object to object, and seeing your work as done.
- Promise: Get excited about gaps you find in the partially shared structure of two different sets of data (i.e., where an analogy appears to fail because it is incomplete). This is a discovery that demands you examine those gaps, develop explanations for them, extract causal principles, identify new questions, and (hopefully!) revise your initial certainties in light of the ways you found the analogy didn't quite work.

Third, exciting scholarly contributions to systems research can be made when analogical reasoning uncovers similar structures across "psychological distance," in "semantically distant domains" (Dietrich, 2010; Liberman & Trope, 2008). It is not easy to detect analogical similarity between one system and one that is seemingly unrelated (in one study only about 20 % of high school students could engage in problem solving that required them to make an analogical connection to a semantically remote problem they had just solved [Gick & Holyoak, 1983)]). As proponents of general systems theory know, identifying analogical similarities in systems that operate in vastly different locations, times, social settings, or hypothetical circumstances is not easy. Perhaps for exactly this reason, it can address important gaps in what is known about the world in which we live.

Competency in Engaging With the Unknown

It is worth stating plainly that writing about skillfully dealing with the unknown feels like an exercise in futility.

Writing that sentence took 8 minutes. Why would that be? If one wishes to write about the unknown, what does one write about? The unknown activates in us a sense of uncertainty, a feeling of inexactness contrasting the feeling of resolution we have when we believe we know something. So, to write of the unknown, we could set out categories of things a systems researcher is unlikely to know at various stages of a research project. We could articulate the kinds of things researchers can know that they do not know, and could contrast them with kinds of things researchers will not know they do not know. Considering each of these, it is difficult to avoid the distinct possibility we have undertaken an exercise in folly. This sense—of being presented with multiple possibilities, any of which could be fruitful or useless—is how the ambiguity of the unknown feels. And, we argue, it is a felt experience that systems researchers must learn to competently engage.

The sense of being in the presence of the unknown is intrinsic to systems research. The systemic phenomena we study are usually rife with unknown interrelationships. They have a propensity for operating in spontaneous, unpredictable ways, described in colorful language such as "the zone of fruitful turbulence" (Smith, 2007) and "the edge of chaos" (Langton, 1990). As discussed in Edson and Klein's Chapter 3 of this book, the ill-defined problems in which systemic processes are implicated are ambiguous. Ambiguity, by its very nature, involves a sense of something going "on both sides" (Partridge, 1958), a Janus-faced acknowledgment that in systems research there are always two (or more) plausible explanations for why a system is behaving as it is. We could remind the reader that the unknown is intrinsic to systems research for all of these reasons, but doing so would place the focus of attention on the external object—on the systems we study.

Instead, we shift from exterior to interior, directing the reader's attention inward. For our experience of the unknown resides within the researcher. And handling one's interior experience of ambiguities and unknowns is a crucial place where systems researchers can operate competently, or otherwise.

Unknowns are the *raison d'être* of research. We engage in research because something is not understood, or at least insufficiently understood. Our objective as researchers is to transform what is unknown into the known. Why people would engage in such difficult work is more than a matter of a cognitively satisfying exercise. Engaging with the unknown is an affectively charged experience as well. Competently engaging with it is a complex cognitive-emotional skill. There are an array of skillful and less-skillful ways researchers can meet the unknown.

In organizational theory, the unknown is problematic—a threat. Seen as disruptive (Ansoff, 1975; Erlenkotter, Sethi, & Okada, 1989), surprises are viewed as unwelcome discontinuities to be avoided (King, 1995; Weick & Sutcliffe, 2001). They signify failure (Buckle, 2005). Beyond corporate life, people find uncertainty threatening (Freud, 1966), and a great deal of human behavior is oriented toward regulating the experience of anxiety it creates (Reiter-Palmon & Robinson, 2009).

There are many ways of meeting the unknown; *avoidance* is one of them. Humans prefer predictability; we have evolved an array of defense mechanisms (individually and collectively) for reducing our discomfort when confronted with unknown or ambiguous circumstances (Argyris, 1986; M. Lewis, 2000). Our modus operandi is to utilize what we know as guideposts to interpret the reality in which we operate. This happens in research as well. When information surfaces indicating that what we know is insufficient for understanding the phenomenon we are researching, our minds often block it out:

> People are self-corrective systems. They are self-corrective against disturbance, and if the obvious is not of a kind that they can easily assimilate without internal disturbance, their self-corrective mechanisms work to sidetrack it, to hide it….Disturbing information can be framed like a pearl so that it doesn't make a nuisance of itself; and this will be done, according to the understanding of…what would be a nuisance. (Bateson, 1972, p. 435)

In other words, one unconscious strategy researchers use to handle the unknown is to avoid seeing it (Budner, 1962).

Researchers also respond to the unknown by working to *reduce* it. As discussed, we analyze large problems by segmenting them into smaller pieces that are easier to handle (Bellak, 1974). We polarize what we perceive into either/or distinctions (Bouchikhi, 1998). We use data reduction strategies to condense large volumes of information into numbers and formats we find easier to handle: in qualitative research techniques like thematic analysis, categorization, and drawing models are designed to reduce the amount of data we work with; in quantitative research, "smoothing" data points to eliminate "noise," and hierarchical cluster analysis are ways to transform much data into much less, for ease of understanding (Aldenderfer & Blashfield, 1984; Miles & Huberman, 1994; Namey, Guest, Thairu, & Johnson, 2007). The challenge of managing the unknown by its reduction, regardless of the data reduction techniques legitimized in our discipline, is that reducing uncertainty with too much conviction or too soon can obscure our ability to perceive connections, to detect relationships in the system under study that may be operating in subtle, yet perhaps potent ways.

A different, equally common response to the unknown is *increase*. An ambiguous situation is "one which cannot be adequately structured or categorized by the individual because of the lack of sufficient cues" (Budner, 1962, p. 30). Accordingly, one way to cope competently with our sense of lack in ambiguous circumstances is to get more information. With more data, the tension of lacking data will ease in us. Of course, with too much more data, the desire to discharge tension by reducing the amount of data we are taking in will intensify. The situation is like walking a razor's edge: between the ambiguity-driven need to gather more information and the ambiguity-driven need to have less information with which to contend. How much information a researcher must get, then, is a challenging judgment call. The easiest way to make it is to defer to tradition, citing the judgment of researchers who have gone before us. Generally, such researchers frame their prescriptions in terms of the demands of the research question and of quality standards established by our academic community. The researcher's own personal ability to cope effectively with the felt experience of having "too much" or "too little" information is rarely considered.

Beyond academic prescriptions, researcher behaviors aimed at data reduction and increase are predicated on one's felt sense of *too*—too much or too little information. This sense of *too* is worth examining for what effects it has on the research, and on the researcher. Implied in *too* is that each of us has some comfortable capacity for carrying some quantity of information at any given time in our research work. Strains to that capacity (in the form of a feeling of too much or too little) get registered by our minds as disturbance, activating our unconscious cognitive strategies for hardening that sense of disturbance into a pearl, as Bateson (1972) has prettily described. Pearl-making is a strategy that accomplishes a satisfying encapsulation of problematic discomfort in our minds; pearl-making also obscures deeper or broader inquiry into the phenomena which is causing the disturbance. This is a critical issue for the systems researcher. Willingness and capacity to take one's inquiry in directions of both depth and breadth is crucial for systemic phenomena. This is guaranteed to bump researchers up against the uncomfortable sense of having too much and too little information. When we seek to foreclose against that discomfort, we sacrifice engaging with the system we are studying in broader and deeper ways.

The matter of *too*, then, is a matter of systems researchers needing to engage in relationship with a large quantity of information with a variety of qualities in a way that is not averse to those quantities and qualities. Humor helps. So also are reminders that research involves swimming in unknown, uncertain territories. The ambiguities we encounter are merely the space where our mental models and real-world phenomena meet in unclear ways; where prior scholars failed to find answers, where no one yet thought to ask the questions you are now, where a newly formed phenomenon does not appear to fit what we already know. Phenomena that do not reward us with easy clarity, that do not reinforce questions that have already been asked and answered—these open new lines of inquiry (McCormick & White, 2000) are desirable (Budner, 1962). Ambiguous phenomena that act on our perceptual apparatus as *too* (-much and -little) and framing these as compelling rather than disturbing, distinguishes skilled systems researchers from others.

By virtue of the complex nature of the systems we like to study, systems researchers place themselves into inquiry spaces that demand considerable *polychronicity*. Polychronicity refers to one's coping capacity in stimulation-rich, information intense environments (Haase, Lee, & Banks, 1979).[1] Researchers, like all people, vary in how polychronic they are, that is, how much information they can accurately perceive in a stimulus-rich environment. Scholarship on this psychological attribute is ongoing, but it seems reasonable to propose a few things:

- If researchers are to account for the real-world complexity inherent in a system they must develop finely tuned polychronic abilities to perceive and interpret a great number of stimuli that vary widely in qualities and intensity, operating across time and space, and exerting varying potency in shaping the system's behavior.
- Systems researchers require greater degrees of polychronicity than researchers who focus their inquiries on smaller or simpler parts of complex phenomena.

The capacity to be polychronic demands an openness to information-dense, ambiguous research settings; that is, it is antithetical to the view that high levels of stimulation and information are threatening.

In the psychological literature, this cognitive capacity is generally framed as "tolerance of ambiguity" (Frenkel-Brunswik, 1949). More than tolerating it, systems researchers must possess great competency in *attuning* to the ambiguities that arise as they engage in systems inquiries. For systems researchers to be highly competent in this area, they must possess: (a) the capacity to take in a great deal of information (polychronicity), and (b) the capacity to skillfully choose how to engage with that information while experiencing the tension produced by simultaneously holding divergent data, apparent incommensurabilities, puzzling paradoxes, and so forth. The urge to discharge this tension is understandable. Indeed, an important function of

[1] As a cognitive construct, polychronicity originated as a term to explain the ways people of different cultures vary in how they detect spatial and temporal cues to structure and understand their environment. Haase and his colleagues have proposed using the construct as a way to study how individuals react and cope when confronted with stimulus-intense, information-overloaded interactions with their environment.

research is probably to reduce some of the existential anxiety inherent in the human condition by discovering[2] order and structure in the world we share. However, it is an important competency for you as a systems researcher to not only tolerate ambiguity by its resolution or elimination, but to become intimately familiar with how ambiguity presents itself to you and how you allow yourself to be informed by it.

Suggestion: Attuning to your experience of ambiguity

Recall a point in your research when you felt bombarded with information. What was your felt experience of being in this polychronous research situation? What can you learn from that felt experience?

Some examples:

- Confusion? This generally signals a conflict between an assumption you had based on prior knowledge or experience versus the real-time phenomenological experience of how the information presented itself to you.
- Annoyance, frustration? This signals the failure of your phenomenon to fit standards you had set, categories you believed in, or mental models you no doubt worked hard to adopt or develop.

The aim in attuning to our experiences of the uncertain, ambiguous unknown is to get to a state of curiosity. The equally important aim is to notice when we are not curious, and to become curious about that! From a place of curiosity, systems researchers can cultivate productive naiveté and useful confusion. With a playful attitude toward the limitations of our knowledge and abilities at any particular point in our research, we can struggle more skillfully. By experiencing at once the intensity of a desire to understand and the awareness that we do not understand how a system works, we train our minds in a keenness of focus and active attention that better enables us to detect the subtle processes of disorder and coalescence that characterize systemic phenomena. Rather than privileging certainty over confusion, systems researchers should actively cultivate ambidexterity in skillfully engaging with both.

Competency in Reflexivity

> Thinking about thought is notoriously difficult.
>
> (Rajahalme (2008, p. 43)

Research implies endurance. It involves sustained attention, "continuous experiential contact" (Seamon & Zajonc, 1998)—months or years of circumambulating a particular phenomenon in the quest for understanding. Every researcher must

[2] (or creating, depending on your ontological beliefs)

become familiar with the tools of the trade: software programs, data collection procedures, the equipment that enable us to do the work we do. The most important of these tools is the person of the researcher her- or himself—the unique constellation of capacities, training, skills, and personality attributes that form the perceptual apparatus central to the research endeavor. As systems researchers, we must become intimately acquainted with ourselves as research instruments—including how we personally think and feel about the work we do. The world of contemporary systems research is one of engagement with complex systems that entrain objects, people, activities, and processes in ways that can be far-reaching, subtle, and potent. As such, we become involved for long periods of time with phenomena producing vast amounts of information for us to assimilate, feeling insistent demands on our attention to consider yet another perspective. We engage with phenomena that, quite likely, will entrain us in their dynamics in unanticipated ways. Systems research implies immersion.

Suggestion: Consider entrainment

- Refers to the ways actors, activities, and objects tend to be pulled into synchronization. By virtue of working on, with, or in a system for a sustained period of time, a systems researcher will observe ways that certain dynamics influence the activity happening therein (McGrath & Rotchford, 1983). Systems researchers are susceptible to entrainment by the same logics operating in the systems they study (Ancona & Chong, 1996). Just as ideas and influences operating a socio-technical system interpenetrate all stakeholders in varying ways, they can likewise penetrate the assumptions and actions of the systems researcher, although we often cannot predict how or when this will occur. Our attunement to a system can lead to entrainment in the very systemic dynamics we study.

As matters of quality assurance and ethics alike, any researcher should become intimately familiar with "our own personal involvement in how we usually meet the world" (Wahl, 2005, p. 62). There is something about researching the systemic nature of nature itself that seems to make deep familiarity with oneself particularly crucial. Systems research seeks to engage directly with how our universe operates in deeply relational ways, expressing coherence and wholeness quite at odds with our scientific traditions of seeing the world as comprised of atomistic parts. Perhaps because of this departure from tradition, discerning systemic wholeness during a research project often involves deeply meaningful moments when one perceives disparate parts of data coalesce in newly seen ways. Theoretical biologists and complexity scholar Brian Goodwin describes such experiences this way:

> [Assembling] observations together to get a coherent whole… is generally accompanied by a sense of the elegance and beauty of the natural world that is experienced as deep aesthetic pleasure. And this is regarded as something of a touchstone for the truth…[it] involves both subjective experience and a qualitative evaluation: elegance, simplicity, beauty, truth, are

> the most common descriptors. The resulting theory often has the property of parsimony. (Goodwin, 1999, “From Quantities to Qualities,” para. 2)

In an atomistic universe, researchers are schooled to view such subjectivity as a threat to high-calibre research. Thus, researchers must continually check their insights against those of “a community of individuals practising procedures of research” (Goodwin, 1999, “Color Experience,” para. 5) appropriate to the phenomenon under study. This is how rigorous research is done.

However, contemporary scholarship calls us to a different relationship with our individual subjectivities. Goodwin (1999) contends:

> There is no intrinsic reason why our feelings should not carry real insight into the nature of the processes we experience in nature. Just as a sense of the elegance, beauty, and truth of the scientific insight are experienced as significant indicators of the real value of an idea, that make sense of the diverse observations, joining them together in a consistent unity, so feelings associated with observations of the phenomena can be significant indicators of their real natures, giving them meaning. (“Color Experience,” para. 5)

It may well be that systemic wholeness is an instance of *qualia*—a quality of nature that can only be subjectively experienced. This suggests we should treat moments of meaningfulness, elegance, parsimony, and so forth in systems research as indicators of potentially important qualities of systemic wholeness, not merely as emotional reactions that cloud our inquiry. Our subjective responses to the systems we research may reveal intrinsic properties of those systems, not merely *our own stuff*.

The art of good research, then, is to use one’s perceptual apparatus in actively receptive ways (Bortoft, 1996) that do not dominate what we observe by our preconceived ideas. At times we must seek to take in information in as unfettered a way as possible; at other times we must seek to impose intellectual structure on what we have perceived (Seamon & Zajonc, 1998). The challenge of research is to recognize that human minds do both. We must work to develop an attunement to when one or the other is holding sway within us.

From a systems perspective, however, one’s subjectivities are not merely private idiosyncrasies. Rather, they are the ways certain systems of thought have claimed us, governing the ways we think and feel, the values we privilege and those we de-emphasize, the normative opinions we hold and the ethics we espouse, the power relations we notice and the thousands of judgment calls we make through the span of a research project. From a systems perspective, objectivities are not unquestionable truths, or “raw reality” (Boulton et al., 2015). Rather, they are products of “science, [which itself is] the expression of a culture…not a given; it implies a construction in which we take part” (Prigogine, 1996, p. 39). In this book, Edson and Klein, Sankaran, and Varey have written about recognized stages of doing good systems research. Their guidance in justifying the ways to design a study, gather data, analyze them and make claims about research findings, are all grounded within the logic of the scholarly and cultural systems in which we are entrained. Your lifelong work as a systems researcher is to take none of those logics as unquestionable, to become intimately acquainted with their merits and blind spots, so you can know what agendas your research is furthering and accept accountability for that.

Conclusion

To conduct systems research is to participate in a form of inquiry that works in a different direction than the *heavily biased* view that the universe is comprised of myriad parts, having relatively little to do with one another.

The atomistic view of the world that separates observer from observed and objects from one another has accomplished tremendous things. More so than any other idea in the history of science, it has enabled us unparalleled understanding of the universe in which we live. As much as systems theorists have critiqued it, we owe much to it. It is likewise true that systems research offers an important complement to traditional modes of inquiry. It allows us to engage more directly with systemic complexity rather than seeking to fragment and simplify it.

It has been said that dealing with complexity "is emotionally as well as intellectually demanding" (Boulton et al., 2015, p. 136). To train oneself to perceive systemic wholeness, with the vast intricacies of relationship that implies, guarantees certain things for the systems researcher. The work will often be confusing. It will frequently feel uncomfortable. It will seem overwhelming.

And if you are seeking to engage in a work and a life informed by the systemic nature of our world, it will be necessary. And quite meaningful.

In this chapter, we have sought to describe several perceptual competencies necessary for the systems researcher. Exciting ongoing research is seeking to identify how to measure and develop these competencies in systems researchers, and to identify other competencies demonstrated by experts in the field. It is unlikely that the competencies discussed in this chapter comprise a comprehensive list of systems research competencies, but we suggest they are fundamental. First among them is the ability to perceive the ways parts and wholeness express one another. The characteristic of systemic complexity demands competencies in perceiving order, change, relationship, and information in a system. Systems researchers must know the difference between using analogical reasoning well and falling prey to naïve analogies. Attuning to the felt experience of the unknown and having strategies for coping with it is important in systems research. Competent systems researchers are reflexive people who seek to understand their unique perceptual strengths and limitations. Together, these competencies contribute to the conduct of effective systems inquiry. In the next chapter, we examine how to evaluate the impact of the systems research we do.

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Chapter 8
Evaluating the Impact of Systems Research

Mary C. Edson and Gary S. Metcalf

Abstract A central challenge of systems research is expressing implicit understanding of change and making it explicit. The goal of this guide is to address, "What distinguishes systems research from other forms of research?" Defining what constitutes good systemic research requires explanation about what is missing from the current practices of research, as driven by the assumptions of science. This requires revisiting assumptions about what we know (ontology), how we learn (epistemology), and how those have shaped our approaches to research thus far. In the seven chapters of this guide, concepts of systems research—philosophy, frameworks, problem structuring and research design, taking action, reporting results, and competencies—have been presented in systematic ways that instill rigor in systemic inquiry. These concepts correspond to the precision expected of science viewed through systemic lenses. Each chapter, and the portion of the research study it represents, needs to be its own coherent "whole," while also acting as part of a comprehensive study design. Good systems research puts science in context; its evaluation requires more than traditional scientific approaches and critical thinking. The need for systemic evaluation prompts several questions concerning the philosophical principles guiding research, the rationale for the chosen framework, the basis for problem analysis and research question development, and the resulting model. Research must be evaluated for systemic coherence as demonstrated in reporting findings, drawing conclusions, and making recommendations. Have the system and the systems researcher been changed by the inquiry? Essentially asking the question: What is systemic about the research and why does it matter?

Keywords Ontology • Epistemology • Systems research • Systematic • Systemic • Systems model • Rigor • Coherence • Context • Critical thinking • Credibility • Evaluation • Change

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M.C. Edson et al. (eds.), *A Guide to Systems Research*, Translational Systems Sciences 10, DOI 10.1007/978-981-10-0263-2_8

What Is Needed and What Is Good Enough?

This book and its organizational model (Fig. 8.1) attempt to span a difficult chasm, with an intention of beginning a process of bringing multiple worldviews into a new coherence. For consideration of our readers, the authors suggest this chasm may be bridged through systems philosophy, processes, and practice. The previous seven chapters have presented different perspectives of the research cycle, viewing it systemically. The intention of this book is to offer diverse approaches to competent and comprehensive inquiry. Like most systems, our attention has been limited to this domain. As a result, these approaches are neither all-encompassing nor conclusive. The focus is on what is needed and what may be good enough to advance our understanding of how and why things work the way they do and possibly what could be changed.

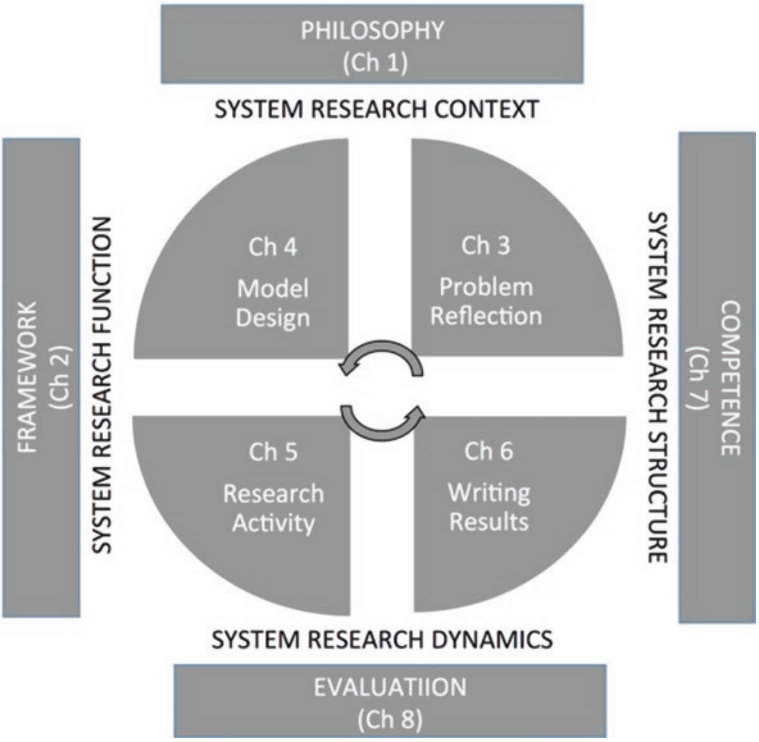

Fig. 8.1 PAR Holon organization of the book chapters

Rigorous scientific research has long been dominated by an emphasis on measurement and verification. Even though science, and most particularly physics, had moved beyond the Newtonian universe over a century ago, the scientific assumptions of that universe have continued to dominate research practices in many ways. This is evident in the standard application of the scientific method in many disciplines with far reaching implications and impact on fields beyond science. The standards of research have included validity, reliability, and generalizability. Representative samples, control groups, double-blind experiments, and rigorous statistical analysis have been the guarantors of the significance of findings. Observation and measurement were the hallmarks of empiricism, the foundation of verifiable knowledge. For the most part, to be "good enough" in science requires the application of the scientific method through testing a hypothesis in a controlled environment. This research strategy closes the system. In reality, the world is an open system. It is an outlier beyond controlled environments.

From the perspective of the social sciences (not to mention the humanities) this approach to research was challenging, at best. The need to force-fit the study of humans into laboratories, or literature and art into measureable variables, created conflicts from philosophical to practical levels. Many disciplines felt pressure to conform in order to "appear scientific," establishing quantitative studies as the only truly acceptable approaches, including management, psychology, economics, and others. There is value in the studies that have been produced, but they often provide a limited view of the subjects in question because the subjects are viewed in isolation equating to a vacuum outside their actual environments.

In addressing complex issues, these approaches remain insufficient. The premise of this book puts forth the proposition that systemic research approaches offer means to develop robust strategies to address complexity. The conundrum of sufficiency is among the issues the authors of this book explored as a collaborative team. An early discussion led to the development of the organizational framework for the book, developed by the authors and first presented by Kineman in Chapter 2.

This version of the framework as the model shown in Fig. 8.1, the PAR Holon organization of the book chapters, puts the eight chapters of the book into the same organizational and structural relationship with each other, as has been proposed that parts of a study be configured. In other words, using the framework, the book chapters reflect how systems research studies may be conceived, conducted, and completed. A critical point to consider is, "What is necessary in order to present an acceptable 'whole phenomenon' in research?" In a self-reflexive manner, this model will be used to talk about the evaluation of systems research. It is a way to consider this book, and the process of research more generally, as a system and broadly as a learning system.

What Is Needed?

In the previous seven chapters, concepts of systems research—philosophy, frameworks, problem structuring and research design, taking action, reporting results, and competencies—have been presented in systematic ways that invoke rigor. These concepts correspond to the precision expected of scientific inquiry. Yet the goal of this book seeks to address, "What distinguishes systems research from other forms of research?" In addition we ask, "What is needed that makes an inquiry systemic?" To answer those intertwined questions, researchers must go beyond systematic criteria (competence) to view inquiry through systemic frames (comprehensive worldview or *Weltanschauung*, defined in Chapter 3). This need for additional systemic evaluation of research prompts key questions based upon the content of each of the previous seven chapters. Here is a summary:

- What philosophical and ethical principles are guiding the research and do they sufficiently reflect a systemic basis for the research? Is the foundation used for the research systemically sound?
- What is the rationale for choosing the framework that will be used for the study, and what attributes have been selected that will represent the system in question?
- How have the problems been defined or research questions been developed? In what ways have these choices defined a whole system to be studied? What rationale was used and what aspects were purposefully included and excluded by virtue of the choices made?
- What is the research design for the study? Does the methodology fit the inquiry? Is it clear that the data selected to be gathered and analyzed will match not only the research design, but also the formal model that is being constructed?
- Is there systemic coherence between the philosophical and ethical principles with the framework, the way the problem has been structured, the research design, and the resulting model developed?
- How will the study be conducted (where, by whom, using what processes, etc.)?
- How will the findings be reported? In what form or format? How does the reporting reflect the dynamics of the system in question?
- What research competencies are required in order for this study to be conducted? Once completed, how have those competencies changed for the researcher?
- What is systemic about this research? Does it reflect properties of a whole system and of the nested "holons" (Koestler, 1967, p. 48; Simon, 1969; Wilber, 2007); that is, the system, environment, and subsystems involved?
- Does the research reflect integrated analysis with integrity in the process?

Remember, each chapter, and the portion of the research study it represents, needs to be its own coherent "whole" (i.e., holon), while also acting as part of a total (e.g., fractal), coherent study design. Like the systems we study, systems research is not merely a sum of parts. It is a system of learning itself. There are multiple scales and potential for self-similarity embedded within the learning system. The implications of these interrelationships will be addressed for each chapter in the following sections using the organizational framework (Fig. 8.1).

Where Do We Begin?

The study of a system could begin from any part of the model. While systems researchers can start at any part of the model, for the purposes of clarity, we will start with the outcomes of reporting (Chapter 6) and work around the model, much like the project management approach suggested in Chapter 3 (e.g., beginning with the end in mind; yet, in systems there is no end, just more learning). Inquiry arises from experience, so ask, "Where am I in the cycle with respect to my experience that compels me to seek out greater understanding?"

With respect to evaluation, which is frequently done in retrospect of an inquiry, it is easiest to begin with the outcome, represented in Fig. 8.1 in the lower right quadrant, labeled Writing Results, referring to Chapter 6. Written results or reporting is equivalent to the observable, measurable variables in a typical study. How would we determine the quality of that outcome? Using this model we could begin by asking, "How were these results produced?" And, "What caused them to come about?" These questions take us back to Chapter 5, the research activity. Note that in this particular model (Fig. 8.1), Chapter 8, evaluation, represents the connection between the outcome and the process (Chapters 6 and 5, respectively), which then makes the sequence logical in that the evaluative question is, "Are the outcomes reported coherent with the research activity?"

These first steps, however, are only the beginning. Remember that we are trying to understand a whole system, not just remove and analyze any isolated part of it. Continuing to move clock-wise through the inner quadrants, Chapter 4, in the upper left quadrant, represents the design of the model used in the research study. The connection between Chapters 4 (the model design) and 5 (the research activity) is done through Chapter 2, the overarching framework of the study. The evaluative question here is, "Does the structure of both the design of the model and study match the research activity?"

Chapter 3 in this model is labeled "problem reflection." This upper right, inner quadrant, is one of the more challenging parts of Aristotle's four causes (material, formal, efficient, and final); the one associated with purpose. In a practical sense, it is often where a study begins. What is it that a researcher has chosen to study, and why is that important? It also contains questions about choices of boundaries and their ethical implications. Not surprisingly, the connection between Chapters 3 and 4 is Chapter 1, the philosophical basis on which a study is built. Philosophical belief systems drive both the purpose and design of a study, whether they are consciously known or not. From an evaluative standpoint, the question arises, "Is the philosophical and ethical foundation for the research systemically sound?"

The next movement around the model goes from purpose and meaning back to the specific data that were chosen. The connection between those, as represented by Chapter 7, is the competency of the researcher(s) in question. With respect to evaluating systems research, this is a difficult but essential question to ask. "Are the researchers in question able to see the connections?" "Do they understand the relationships between different but interrelated and embedded 'wholes'?" "Do they see the connections between the specific data that they have chosen to study and the purpose and meaning of the study as a whole?"

Looking at parts of the model can also help us understand some of the challenges about research and the need for a larger perspective. The bottom two inner quadrants (Chapters 5 and 6 in Fig. 8.1), if isolated, represent mechanical systems. They explain observed behavior and immediate causality of that behavior, but that is all. This is typical of many quantitative studies that get published in academic journals. It is also typical of the way that research gets taught in far too many institutions. Students choose a topic and propose hypotheses based on assumptions about the relationships between variables. They select data from existing datasets of information, often with little or no real understanding about who produced the data or how, much less why. They run statistical analyses on the data using predetermined tests of significance, and then present the results. Assuming that statistical significance is shown, they report their hypotheses to be supported (or their null hypotheses not to be supported, more accurately).

In fairness, unspoken assumptions reside in the backgrounds of many such studies. If researchers are explicitly building on the work of closely related colleagues or fellow researchers, then stating every underlying assumption explicitly would simply be a waste of time and energy. The prevailing wisdom is that they are "adding to the body of knowledge" of a given domain. The incremental evolution is considered the researcher's contribution. A generally accepted standard of practice in traditional research in many scientific fields is to present findings of statistical significance. Then, in the process of presenting results, researchers attempt to explain them through some levels of causality that are not necessarily supported by the studies themselves. This disparity would become apparent if the questions posed by this model were addressed.

On the other side of the chasm, research studies can be described using only the top two inner quadrants of Fig. 8.1. In isolation, these quadrants represent many qualitative studies where belief systems encompass most of the research, involving every manner of human connectedness, political and social correctness, respect for diversity, and concerns for emancipation. Unfortunately, many of these studies lack not only testable findings, but any significant amount of rigor, and often of defensibility beyond the immediate settings in which they were conducted.

As above, there are often missing arguments as to why research approaches have evolved as they have. Not only are there problems with trying to force phenomena into data-forms which do not fit, there are also legitimate questions about human objectivity when approached in terms of Newtonian science. As stated earlier, simply turning a variable into a number does not make it more accurate. In many cases, it can strip it of meaning and connection relative to what it was intended to represent.

What Is Missing?

Defining what constitutes good systemic research requires some explanation about what is missing from the current practices of research, as driven by the assumptions of science—primarily physics (Agassi, 1968). To do that requires examining assumptions about what we know (ontology), how we go about learning (epistemology), and how those have shaped our approaches to research thus far (Boorstin, 1983). Remember, too, that what we formally consider to be science only began around 1600 A.D. even though the roots of those ideas began at least 2000 years earlier. To a large extent, what we are calling "systemic" goes back equally far (or could be thousands of years older), but got lost along the way (Clagett, 1955; Golinski, 2005; Kuhn, 1962).

So what is a systemic approach to research? From a philosophical perspective, consider that formal research is just one of many ways in which people try to learn about or understand the worlds in which they live. Kineman laid a foundation in this book in Chapter 2 through references to Rosen's (1991) modeling relation, which can be seen as a general description of the practice of science, as well as his proposition that R-Theory[1] might represent a universal process of learning found in nature. Learning begins from the moment we are born and continues in various ways throughout our lives (Popper, 1972). It starts from our most immediate surroundings and sensations (sight, sound, touch, taste, and smell). It is initially guided through caregivers, and as we acquire language we gain the ability to learn, symbolically, what others know and believe. At some point, most people discover that there are multiple explanations for the same phenomena in the world, and they have to decide how to choose what they believe.

A default, for many millennia (and still true for many people today), was to trust authority figures for knowledge. This is evident in the evolution of centers of power with those who organized and had the biggest buildings—such as churches, then governments along with public institutions, and now corporations (Hall, 1959, 1966, 1976; Hall & Hall, 1995). Those figures came in the form of parents, teachers, spiritual and religious leaders, those in political power, and eventually in the form of written documents. Also for millennia, explanations about the universe appeared in forms that we would now call myths and mysticism. Those generally involved spiritual beings of some form who caused or controlled occurrences in nature, through super-human (but human-like) abilities.

[1] R-theory describes a closed causal unit of nature, called the "holon," which is a Rosen modelling relation between category theoretic mappings (integrating both concepts). R-theory provides a new method of analysis that can relate whole and fractioned (mechanistic) aspects of nature (Kineman, 2012).

When people in ancient times viewed the stars at night, they saw gods and goddesses in the form of constellations. Rich and complicated mythologies developed about which gods controlled which aspects of nature and the relationships between them. Most every ancient civilization had its own version.

Ancient Greece had a particularly well developed body of myth, led by the god Zeus who ruled over Mount Olympus. Out of this tradition, though, evolved new ways of thinking which set the stage for the development of Western thought and modern science.

By the fifth century B.C., the theory of atomism had been developed, which proposed that "The world was composed exclusively of uncaused and immutable material atoms—a unity changeless substance" (Tarnas, 1991, p. 21). It was also the Greeks who brought a notion of mathematical order to the understanding of the universe.

Plato focused on the study of the cosmos as particularly important. No longer were the heavens ruled and populated by gods and goddesses. Stars and planets were material bodies following patterns of order, yet to be discovered. It was this connection to astronomy that would create the foundation for modern science.

> For the riddle of the planets, as formulated by Plato, and the long and arduous intellectual struggle to solve it, would culminate two thousand years later in the work of Copernicus and Kepler and their initiation of the Scientific Revolution. (Tarnas, 1991, p. 48)

According to Tarnas (1991), it was Galileo who established a new standard for science. Rather than following the ideas of Aristotle (a descriptive biologist), Galileo chose the work of Archimedes, a mathematical physicist.

> To combat the Aristotelians, Galileo developed both a new procedure for analyzing phenomena and a new basis for testing theories. He argued that to make accurate judgments concerning nature, scientists should consider only precisely measured "objective" qualities (size, shape, number, weight, motion) while merely perceptible qualities (color, sound, taste, touch, smell) should be ignored as subjective and ephemeral. Only by means of an exclusive quantitative analysis could science attain certain knowledge of the world (Tarnas, 1991, p. 263).

This brings us to the point where Whitehead (1925/1967) explained more directly many of the problems that we still face. As he stated these:

> Galileo keeps harping on how things happen, whereas his adversaries had a complete theory as to why things happen.…It was a great mistake to conceive this historical revolt as an appeal to reason. On the contrary, it was through and through an anti-intellectual movement. It was the return of brute fact; and it was based on a recoil from the inflexible rationality of medieval thought. (p. 8)

Whitehead (1925/1967) went on to explain the impacts that this turn in science created.

> Science has never shaken off the impress of its origin in the historical revolt of the later Renaissance. It has remained predominantly an anti-rationalistic movement, based upon a naïve faith. What reasoning it has wanted has been borrowed from mathematics which is a surviving relic of Greek rationalism, following the deductive method. Science repudiates philosophy. In other words, it has never cared to justify its faith or to explain its meanings. (p. 16)

Because this version of science has not endeavored to answer these larger questions, it leaves much open to interpretation. While providing insight into questions, in and of itself, traditional science is insufficient because it leaves questions of relevance to lived experience of the world unanswered. This gives cause to a search for fuller explanations for understanding the world around us. A systems approach, one that accounts for the context in which phenomena occur and operate, may inform these larger questions. Good systems research addresses complexity of these questions with comprehensive approaches that bridge the chasm scientific reduction leaves open. Systemic inquiry does not break down complex systems into parts with an expectation that doing so sufficiently explains how the world works. Adept systems research clearly describes the system and its complex relationships for understanding, using multiple perspectives and levels of analysis. Robust descriptions of systems enable insight and analysis revealing leverage points for choice or decision making depending on the desired outcome, for example stasis, intervention, and/or change. Good systems research values the process, progress, and products of the scientific method while providing additional insight gained through systemic approaches to inquiry. Systems researchers use scientific and systemic approaches in concert to bridge the gaps.

Toward a Systemic Perspective

A systemic approach to research seeks to understand whole entities and their relationships, in the context of relevant environments. Until we are able to comprehend the universe in its entirety, we are forced to make choices about distinctions. Where do we draw boundaries between a system and its environment? What is necessary to include as part of a system, and what is actually only a factor in the environment, or part of a related but different system? Even what we assume as being simplest and most obvious can change through different perspectives. There are some general principles, though, from which to begin.

It is easiest for most people to think in terms of physical objects, because that is how we first encounter the world. A bicycle has been used as an example (Ackoff & Emery, 1972, p. 32) because it takes on the properties of a functioning whole when the parts are assembled in certain relationships. There is no clear "origin" to the bicycle (no historical record of the first specimen) and different versions of history trace the original concepts to anywhere between the 15th and 19th centuries. By the early nineteenth century, though, bicycles were present and starting to flourish. For simplicity's sake, consider a bicycle as a machine with two wheels, used for human transportation, powered by a human using pedals. There are many variations of the structure of different bicycles, as well as of the materials used in their construction. Bicycles are ridden by animals in circuses, but that is an adaptation of the animal rather than the bicycle itself. In some general sense, we can distinguish bicycles from not-bicycles.

If we were to conduct research about bicycles, we could approach that simply by focusing on the bicycle itself. First, does it meet the definition of being a bicycle (e.g., human-powered transportation machine with two wheels)? If so, then how do we explain a bicycle? As a machine, it is relatively simple, but coming up with the concept was pretty ingenious (combining the efficiency of wheels with a human "engine"). There are many variations using high-tech, high-cost materials, making them very expensive. In several cities (e.g., Beijing, Shanghai, Amsterdam, Copenhagen, and soon possibly London) bicycles outnumber cars (O'Sullivan, 2016). All of these could be relevant variables about bicycles, but to what extent would they help to understand or explain a bicycle?

Another way to approach the question is to ask, "Why a bicycle?" Bicycles are machines, and they do not create themselves. Bicycles are created through a combination of humans and tools, using the materials selected. But bicycles are also created from some concept of a bicycle. As noted above, there does not appear to be a clear, historical origin of the bicycle, but every time that one is produced it follows some variation of a relatively stable pattern. And as means of transportation, bicycles are produced with some functional purpose in mind, whether for commuting to work, carrying loads of farm produce, or racing in the *Tour de France*.

These simple ways of explaining a bicycle can be mapped to Kineman's model from Chapters 2 and 4, in relation to Aristotle's four causes. The parts and materials that we see and can measure are the material causes of a bicycle. The crafts-people who make a bicycle are the efficient cause. The design concepts behind the configuration of a particular bicycle are the formal cause, and the purpose-in-use of that model of a bicycle is the final cause. As should become apparent, all of these causes are intimately interconnected and interdependent with each other.

As we consider a process of evaluation, then, we begin with Chapter 6 of the model in Fig. 8.1, in the lower right quadrant, which focuses on reporting results of the research. Beginning with the output from the study indicates whether a researcher's intention, design, and execution were brought to fruition and whether the outcomes were as anticipated or new information emerged.

Reporting What Happened

Chapter 6 takes us into the realm of conveying to others what we have learned from a research study. Varey (2016) describes the challenges this poses for systems research elegantly:

> If we take a moment to reflect on the question, "What is unique about systems research?" it is not surprising that doing system research generates questions about the forms and functions of research itself. There are three systemic features that become immediately apparent in a systems context. These relate directly to (a) the appropriateness of the research form, (b) the structure of the parts, and (c) the efficacy of the whole. These three considerations are central to a systems approach generally. The systemic elements of the research itself can be

> analyzed similarly. They highlight the *concept*, *composition*, and *concordance* of the research process being reported. Together these constitute a useful systems research aesthetic.
>
> An aesthetic test for reporting on systems research is to confirm the researcher has considered these features by identifying: the systemic boundary (of assumptions), the system of relations (in the composition), and the totality of effect (from their combinations). An elegant piece of systems research will potentially have each of these elements in harmony. For the systems thinker, elegant research has a balance in these elements intuitively. The skillful systems researcher may even embody *systemic beauty* in their research design consciously. (pp. 146–147)

The distinctions between systematic (systems as context), systems (as the content of a study), and systemic (as concept in a study) are also quite useful. And as Varey sums up one aspect of adequate research reporting:

> In writing-up systems research, the report of the research will ideally (even if briefly) situate the choices of: (a) system philosophy, (b) epistemological framework, (c) systems research methodology, (d) paradigm axiology, and (e) form of system depiction, as components within a totality. The researcher should justify each selection with reference to the other elements of composition. In this way, the research as a whole may be considered to include "informed, relevant, appropriate, significant, and representative" elements (Varey, 2013). (Varey, 2016, p. 154)

The goal is to report something that represents at least an aspect of wholeness; a description of dynamic entities as they exist and evolve in an ever-changing world of only relative stability. This requires that we capture not just an entity unto itself, but the patterns and processes that constitute that entity, or system, or subject of study.

Rosen's (1991) modeling relation has been proposed in this book as the foundation for systemic modeling (the representation of the research results). That is elaborated further through the R-Theory models presented in Chapters 2 and 4 (Kineman, 2012). Those specific models, and other variations offered in this book, are not intended as the only means of adequately describing research. They are meant, though, as examples of what might be adequate.

Within the model for this book, each aspect of a research study should be both whole and part; it should be complete unto itself, and it should be clearly connected and coherent.

Focusing on the reported results of a study, how clear, accurate, and complete is the model of what is presented (or represented)? In terms of the modeling relation, how closely does it replicate the phenomena that have been studied? If the model is "decoded" back into the natural world, how well does it fit? Does it explain the "thing unto itself" as well as the "thing" in relation to its environment, as both evolve in relation to each other through time?

In more practical terms, if you read the results of any given research study, what do they tell you? Do they explain both "what" and "why" about the system or subject in question (revisit the bicycle example)?

Self-referentially, does the research report (thesis, dissertation, etc.) explain the "what's and why's" about itself? Does the research report give you a clear understanding about how the study was conducted, including the concepts and design which produced it, as well as the bodies of knowledge and thinking from which it came?

It is unlikely that many existing studies fit all of the criteria that have been presented. In many ways, this is an idealized design (Ackoff, Magidson, & Addison,

2006) for modeling that will help to guide research into its next phases of development. In the future, it would seem probable that computer-driven models (or the next, further developments in technology) might provide more complete and dynamic representations of the systems that we attempt to understand. If so, creating those models will not be only a matter of more data. They will require different types of data, adequate to the wholeness of the systems in question, and new ways of displaying behaviors through means that we can comprehend.

Referring again to Fig. 8.1, evaluation connects research results with the research activities that produced them. That sets the stage for the next section of this chapter. It is also important to note, though, a connection which Varey (2016) emphasized several times, as captured in his words from Chapter 6:

> The way in which research choices form and shape a systematic research approach can be examined systemically. This "systems approach to systems research" is described as the testing of philosophical concordance (Varey, 2013). The proposition is that good systems research design should ostensibly contain an alignment between the philosophically critical elements adopted for good researching. (p. 153)

In this regard, writing up results of systems research is necessarily explicit and reflective about what happened in the system and what happened to the researcher.

Investigating the Subject System

Chapter 5, shown in the lower left quadrant of Fig. 8.1, takes us into the realm of research as an active process, that is, actually conducting the research study which was designed. Doing so inevitably revisits each of the previous chapters. How did we envision the study that we set out to do and ourselves in relation to it? How were the research questions created and what did those imply about the kind of model (in a general sense) that would result? How did those answers then shape the problem structuring and design of the study that was intended? How was the setting for the study, and the participants, chosen? And how did all of those factors begin to shape the elements that would create the model (the results) of the study? An overarching question that can be inferred from Chapter 5 is, "What actions occurred that brought about the results presented?"

Many researchers, especially as early students, begin studies assuming that most of the processes are relatively simple and often self-evident: Find a topic of interest, determine a place to gather data, then analyze the data, and report the findings. Many of those same students are frequently surprised at the number of unexpected occurrences that happen in the midst of conducting a study. Choosing a highly interesting topic does not necessarily make getting access to the right kind of data easy. There are protocols to be followed for most studies (e.g., legal and ethical standards to be met, such as dealing with endangered species, human subject protections, or sensitive cultural issues), some specified by Institutional Review Boards (IRBs). Beyond that, almost every study involves the cooperation of other people whose involvement is necessary, but who are not necessarily interested or invested in your study.

Not only does a research study need to be designed, it also needs to be managed. As Sankaran has described in Chapter 5, thinking of this in terms of project management can be helpful. It is useful to set timelines for each stage and activity, and to map out (more or less formally) the processes and people who need to be involved. In larger studies, researchers may consider using project management software to keep track of tasks, milestones, resources, personnel, and participants. Use of these tools can help document the activities of the study or latter analysis.

More generally, it is also useful to think of the interactive stages of participatory action research (PAR) as a path through which a researcher will walk many times during a research study. As described in Chapter 2 (Fig. 8.2), this is not a closed circle of steps, but a spiral which moves forward as you cycle through it. It is a process of engaged involvement between the researcher and the participants, as well as the subject in question. It is a process of learning through change, on all parts.

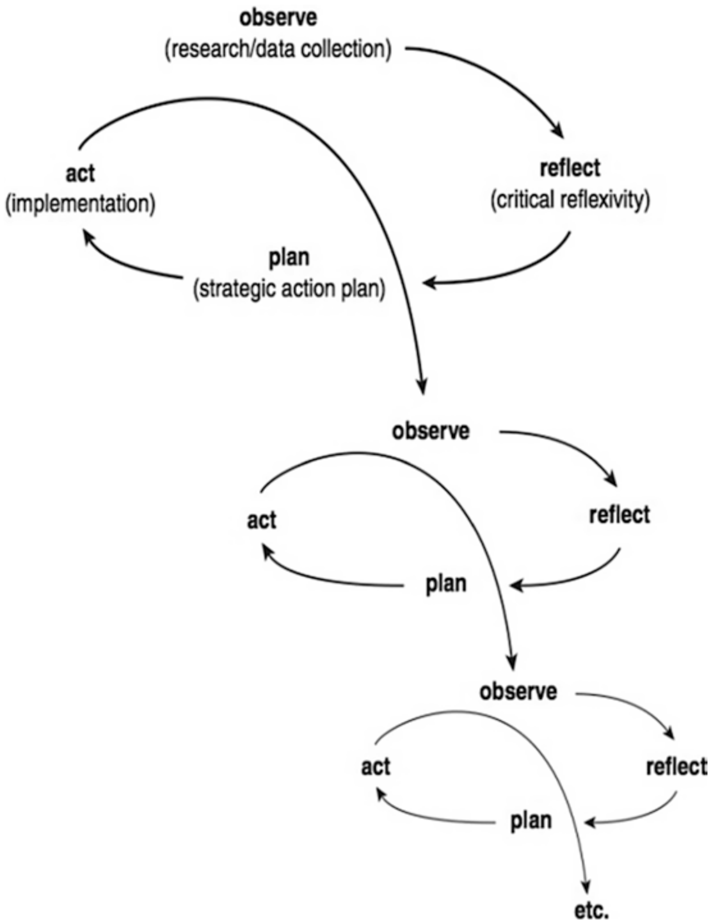

Fig. 8.2 Cycles in action research (O'Leary, 2004, p. 141)

An important question with respect to the implementation of a PAR study regards the "P" (i.e., participatory or participation). In social systems research, ideally, the participants act as co-researchers. They learn together along with the researcher, both from an ethical standpoint (most should have a right to be involved rather than "be studied") and from the practical perspective that they often already know much more about the system than anyone who might come in from the outside.

For research that does not involve human participants, a question is then whether there is a way to "engage with" the system in question. Are there safe and ethical ways to try to understand a system as it naturally functions—to capture the dynamics of the system as it behaves and evolves? For many types of studies, that question may seem out of place (e.g., research about animals in natural habitats, or climate studies, etc.). Ultimately, though, there is usually a desire to understand a system "as it is," in order to create the closest match possible between the formal and natural systems of the modeling relation.

Once completed, was the process itself coherent? As a systems researcher, it is important to be mindful of the drive to rationalize discrepancies and incongruities between what was anticipated during the design of a research study, despite accounting for context and boundaries, and actual behavior of a realized system. Ideally, these incommensurables should be acknowledged, duly explained, and documented for future research, which is the focus of Chapter 6.

Assessing the wholeness of the data gathering and analysis in a research project is dependent upon the connection with the design for the study, based upon the original intent for what was to be learned. That takes us back to the model design in Chapter 4, in the upper left quadrant of Fig. 8.1. Upon reflection of the actions taken during data gathering and subsequent analysis, did the methods implemented fulfill the vision proposed by the model? To assess this, researchers and their evaluators examine the cogence of the model.

Transforming a Description of the Subject System into a Model

In Chapter 4, Kineman (2012) builds upon the models from R-Theory as a way of capturing whole systems in research. While there are no absolute standards for the types of data or models used in PAR, the choices made should fit the intent of the study. The data selected should reflect the phenomena being studied, which will then be used to create a model most suited to the system in question; this is the process of encoding and decoding in the modeling relation.

An obvious question at this point might be, "Can you design a study specifically to be systemic?" More bluntly, "Can the design of a research study guarantee anything about the systemic quality of the processes or outcomes?" The simple answer is "no." None of the research methodologies described in this section is inherently systemic, in and of itself. A PAR study can be conducted focusing solely on mechanistic processes and material causes—and many have been. An approach to understanding systems in action, however, greatly increases the chance of researchers observing and experiencing the connections within systems and environments that could be of significance. It is then a matter of capturing those elements and relationships in ways which provide descriptions dynamic and evolving entities.

In order to achieve a level of mathematical rigor in systemic models, without forcing a reduction of the phenomena to numbers, Kineman suggests using symbols adapted from category theory (the varying lines and arrowheads described in Chapter 4). While this symbolic system may be challenging for many students and researchers who are not familiar with advanced mathematics, four-quadrant models may still prove to be useful and adequate.

The most familiar action research processes follow a 4-step model, often labeled as Plan, Act, Observe, and Reflect. For comparison, Fig. 8.3 shows four other variations of research approaches. All of these map to 7-step processes, which might also be correlated with the chapters in this book. Chapter 1 of the book, regarding philosophy, falls into the background of thinking about research, so Step 1 of the diagram correlates with Chapter 2 of the book, and so on—though not always in exact order.

The action research approaches shown include the Soft Systems Methodology (SSI; Checkland, 1999), Evolutionary Learning Labs (ELL; Bosch, Nguyen, Maeno, & Yasui, 2013), and a process used by the International Council on Systems Engineering (INCOSE, n.d.), referred to as SIMILAR (*S*tate, *I*nvestigate, *M*odel, *I*ntegrate, *L*aunch, *A*ssess, and *R*e-evaluate). Also included is a slight modification of the social research process described by Ackoff (1953).

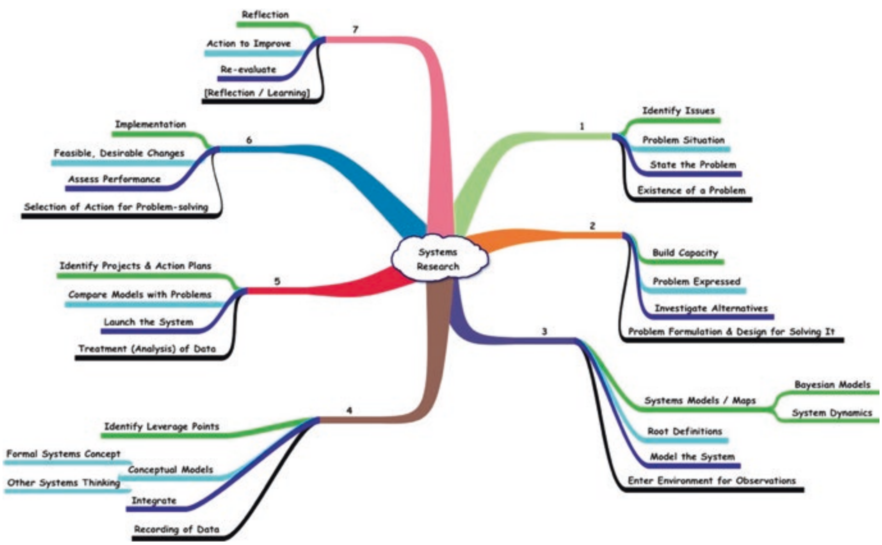

Fig. 8.3 Systems research model (Metcalf, 2016). Combining four versions of action research, in order from top to bottom of each branch (Incorporating Evolutionary Learning Labs, Soft Systems Methodology, SIMILAR, and Ackoff, 1953)

Step 1 of each process involves the choice of a system or a problem. That is also the drawing of a boundary between system and environment for the study. It indicates how the initial problem or system is framed, which then sets the stage for the kind of methodology appropriate to studying the problem, the kind of data needed to address or answer the research question, and so on. For the SIMILAR model, this is more like customer requirements or desired outcomes of a design.

Step 2 moves in slightly different directions according to the type of PAR used. ELL uses this step to identify the capacities of the participants and communities involved in the project. SSM continues from Step 1, in describing the situation in which the problem in question exists (Checkland, 1999). Ackoff (1953) explored potential solutions at this step, and SIMILAR evaluates possible design solutions.

In Step 3, both ELL and SIMILAR develop models. For ELL, these are typically System Dynamics models (Forrester, 1958, 1961) and Bayesian network diagrams (Pearl, 2000; Pearl & Russell, 1998), capturing the dynamic processes and alternative decision influences in a given situation. For SIMILAR, models may include: "physical analogs, analytic equations, state machines, block diagrams, functional flow diagrams, object-oriented models, computer simulations and mental models" (INCOSE, n.d., "Model the System," para. 1). At this stage, the general model for the entire process or project is also determined. SSM moves to root definitions, which are intended to describe the fundamental nature of the systems which are being studied. This is the stage at which Ackoff (1953) suggests to conduct observations and gather data.

Step 4 for ELL involves identifying leverage points, or those places where interventions will have the highest probabilities of impact. This comes from the use of the models in Step 3, in which situation is described and alternatives evaluated. For SSM, this is the stage at which models are constructed. Checkland (1999) described this stage:

> We now build the model which will accomplish what is defined in the root definition. The definition is an account of what the system *is*; the conceptual model is an account of the activities which the system must *do* in order to *be* the system named in the definition. (p. 169)

Checkland cautions against misinterpreting formal models as realities. Models are perceptions (cognitive constructs) of how things might be, not what they are in the real world. Instead, "it is simply the structured set of activities which logic requires in a notional system which is to be that defined in the root definition" (Checkland, 1999, p. 170). The model is built on verbs, describing the activities required by the system. Checkland further defines what he means by a model, in this way:

> S is a 'formal system' if, and only if: (i) S has an ongoing purpose or mission… (ii) S has a measure of performance… (iii) S contains a decision-taking process… (iv) S has components which are themselves systems having all the properties of S… (v) S has components which interact, which show a degree of connectivity… (vi) S exists in wider systems and/or environments with which it interacts… (vii) S has a boundary… (viii) S has resources… [and] (ix) S has some guarantee of continuity, is not ephemeral, has 'long-term stability', will recover stability after some degree of disturbance. (pp. 173–174)

Step 4 represents the integration phase of the SIMILAR approach, in which the parts of the developing model are brought together. Specifically, this requires identifying subsystems within the larger system, as well as the interfaces between subsystems and the feedback activities involved. For Ackoff's (1953) methodology, data from observations are recorded (and by interpretation, these become the elements of the formal system).

Step 5 for ELL involves planning for interventions into the system. All of the gathering and analysis of data, along with identification of stakeholders and resources available, and the leverage points to be targeted, culminate in plans to attempt to improve the situation in question. For SSM, the conceptual model which has been built is compared to the real-world situation being examined. This appears to be like the comparison between the formal and natural systems of Rosen's modeling relation. For SIMILAR, "launching the system means allowing the system do what it was intended to do" (INCOSE, n.d., "Launch the System," para. 1). The system chosen from the alternatives is designed in detail and produced. For Ackoff (1953), data from observations in the study is treated (analyzed) by the scientist or researcher.

Step 6 of this cycle is about implementation and assessment, according to the different approaches. For ELL, this is putting plans into action. For SIMILAR, this step involves assessing the model as it was put into action in Step 5. For Ackoff (1953), results are given back to the customer of the research process. In SSM, feasible and desirable changes are implemented. According to Checkland (1999), changes can be of three kinds: in structure, in procedures, or in attitudes.

Step 7 is both reflective and preparatory. This is the step at which the entire cycle is evaluated for quality, effectiveness, and so on. Based upon the outcomes of the assessment, a new cycle of learning or intervention begins.

Note that the 7th step was added to Ackoff's (1953) approach in this model. As with most traditional research, there is no assumption of process evaluation or learning which is built upon. The assumption has been that scientific research would "add to the body of knowledge" in a given field of study, and therefore be a part of ongoing learning, presumably. In the practicality of most organizational research or consulting, as much of his work was applied, projects end when results are presented, and only occasionally carry forward into continuing projects. For SSM, this phase is just an extension of Step 6, as changes are implemented and evaluated. For SIMILAR, this is considered possibly the most important step, understanding what worked, what did not, and what improvements need to be made.

Most PAR studies value the creation of change in a system over the development or testing of theories. Outcomes of such studies are often just the documentation of the processes used and the changes noted. That can be valid in its own realm, where research itself is considered to be made meaningful through its improvement of human conditions. Historically, though, most qualitative studies are never brought together, or built upon each other, to create larger or more specific models of systems.

Based upon these four examples of PAR, there is no reason why the results could not be presented in more scientific terms, other than the typical processes and projects chosen. Each of the examples uses, or could use, very rigorous models as parts of the processes employed (for instance, the system dynamics and Bayesian models of ELL). The model derived from R-Theory, by Kineman, advocates for bringing concepts from traditional, physics-based science and the qualitative approaches typical of social science research together.

Other research methodologies, beyond PAR, are also amenable to being used in a systemic study. Case study, for example, "explores a real-life, contemporary bounded system…over time, through detailed, in-depth data collection involving multiple sources of information" (Creswell, 2013, p. 97). What are missing from a typical study are the connections with the context or environment, but those could be added without conflict with the methodology itself. Grounded theory also aligns easily with systems research, in that it provides an open process of investigation resulting in the presentation of a theory or model. Working towards a holistic framework as the template for the model would actually add a great deal of simplicity and value to most grounded theory studies. Mixed methods research appears to span the chasm referred to at the beginning of this chapter, by including both qualitative and quantitative forms of data. While that approach can certainly help create more complete descriptions of a subject of study, it does not necessarily create a model that maps (decodes) back to explain both the "whats and whys" of a system as it evolves through time.

In Chapter 4, Kineman explains that rigorous and defensible practice depends upon established rules and principles designed specifically for the subject system. He states: "Good system research depends on being aware of what kind of activity and aspect of the system the researcher is engaged in, and then applying appropriate methods and tests" (Kineman, 2016a, p. 103).

Chapter 4 of this book demonstrates a model while explaining the role of modeling in describing a subject system. Before moving into conducting the study, a systems researcher needs to evaluate the research strategy. Again, the framework introduced in Chapter 2 is useful in evaluation of the research plan, by providing the basis of questions that a researcher can ask, such as, "Is there systemic coherence in the approach to the research incorporating philosophy, frameworks, problem structuring, research design, and modeling?" Among the aspects of the subject system (contextual and realized), have epistemology and ontology been sufficiently addressed through structure and function? If so, does the research study have an explicit plan for tracking these elements through the next phases of the study? If so, a systems researcher can undertake the next steps with confidence that the approach is sound, even though the actual outcomes have yet to emerge. As noted in Fig. 8.1, Chapter 2 is the connection between the research design and the research activity.

Frameworks

Kineman uses Rosen's (1985) modeling relation as a foundation for Chapter 2. This explains the connections between *formal systems* (in his descriptions, mathematical models) and *natural systems* (the actual or real-world phenomenon). Formal systems become our explanatory models. They are created through the results of our research studies. What did we learn, and based upon that knowledge, what more can we explain about the things we set out to study?

Encoding is the process of choosing and entering variables that will be included in a formal system or model that attempts to describe a natural system to whatever degree of specificity chosen (contextual or formal/final). Decoding is the process of testing the model against reality, the natural system (actual, efficient/material). How closely does it match, or how completely does it explain the system, and can it predict the future behavior in question?

At the most general level, models are explanations. As Rosen (1991) stated,

> As we have seen, the modeling relation is intimately tied up with the notion of prediction. Natural Law, as embodied in modeling relations, thus equips us to look into the future of things; insofar as the future is entailed by the present, and insofar as the entailment structure itself is captured in a congruent model, we can actually, in a sense, pull the future of our natural system into the present. The benevolences of Natural Law lies in assuring us that such miracles are open to us, but it does not extend to telling us how to accomplish them; it is for us to discover the keys, the encodings and decodings, by which they can be brought to pass. (p. 64)

From that perspective, models can vary greatly with respect to how detailed, complete, or exact they may be—or need to be. Mental models, for instance, describe something like heuristics—*rules of thumb*—which act as frames of reference for how individuals see or interpret the world. Conceptual models can be early sketches of a process or product, intended to capture macro-level ideas with end users or nontechnical decision-makers. More exact and detailed models include blueprints and specifications in Computer Assisted Design programs. Scientific theories fall at the far end of this spectrum, attempting to describe the very essence of a phenomenon in a causal and predictive form. At present, the most exact scientific theories still tend to be expressed in mathematical equations.

Models, including scientific models, often begin with metaphor. According to Rosen (1991), proceeding from metaphor is "not an unreasonable thing to do" (p. 66). However, Natural Law exacts a cost for prediction and necessitates finding the right encodings (i.e., formal descriptions of variables in a study). If we presume otherwise, as in metaphor, we only have half of the modeling relation, which is essentially decoding without explicitly encoding. Rosen acknowledged the role of metaphor in science, especially biological science in its adoption of the machine metaphor introduced by Descartes. Again, Rosen explicates about another important metaphor often used in systems science, the open system, proposed by von Bertalanffy (1969). Rosen (1991) stated,

> Bertalanffy drew attention in particular to the metaphorical relation between what happens in the vicinity of stable point attractors (stable steady states) of open systems and the empirical facts of embryonic development: pattern generation or morphogenesis. In this metaphor, we seek to decode from the former into the details of the latter, again without the benefit of any specific encodings going the other way. It was this general metaphor, embodied in particular submetaphors by Rashevsky and Turing, that sent physicists like Prigogine scrambling to modify thermodynamics to accommodate them. (p. 65)

Experimentalists find metaphor problematic because verifiability is imprecise. As a result, they rely on specific encoding. The hostility of empiricists to theory expressed in metaphorical terms is a disparity between encoding and decoding. Since science currently relies on verification, metaphor is not considered science, even though it "can embody a great deal of truth" (Rosen, 1991, p. 66). Metaphor can be formalized, as in category theory, specifically in its concept of functor (Arzi-Gonczarowski, 1999; Kuhn & Frank, 1991). As metaphors illustrate similarities between two ideas or concepts, functors map between categories. Both infer similarity through relationship between entities, yet to differing degrees.

Social science research, especially when using qualitative approaches, tends to remain in the realm of metaphor. There are often good reasons for doing so. Simply representing a characteristic in research as a number does not make it a measurable variable. Assuming that those numbers can be calculated for statistical significance only compounds the problems.

Learning does not inherently require statistical or numerical calculations. The roots of PAR were founded in human collaboration, through learning about social systems with the people who created and perpetuated those systems. Typically, those participants were not scientists, and their language was not mathematics. Even so, tremendous value could be produced through the processes of learning together.

On the other hand, the weakness of much social science research is that it has remained content with staying at the level of generalities and metaphor. The problem is not necessarily in the language or representation (e.g., mathematics) but in the clarity and specificity of the phenomena being studied.

None of these approaches or models of research is necessarily right or wrong, or inherently "better" than the others. Each represents a different need or intent. The only caution is that the model should be coherent; it should represent "what it is" and not claim or attempt to be something else. (That is a frequent weakness of research studies, many of which claim to explain fundamental principles of a system or entity, when they actually have only described correlations limited to specific times and locations.)

In terms of the modeling relation, the question for evaluation is how closely the formal model (the one we create) replicates or explains the natural model (the one that is being studied). From Chapter 2, the Relational Holon, shown in Fig. 8.4, represents a general way of conceptualizing the aspects of a system that one would hope to capture in a model.

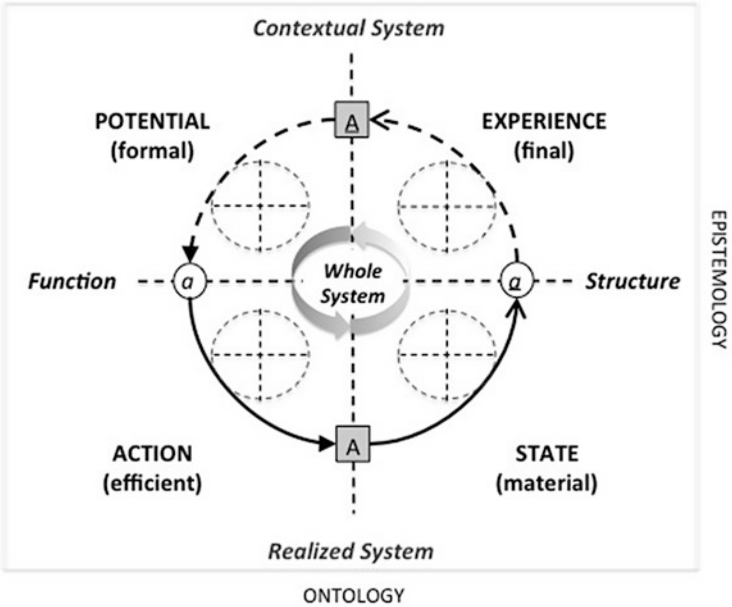

Fig. 8.4 Relational holon

Research that is limited to what Whitehead (1925/1967) called scientific materialism falls into the lower two quadrants of this model (dynamic processes and observable occurrences). Those address what is happening, but not why. The data and analyses in that kind of study may be highly accurate, but will still be restricted to the limitations of the questions and design of the research. Unfortunately, many published studies report strong correlations based on statistical analyses, and then offer conjectures about the reasons for the behavior without further support for them.

In the end, there are "best explanations" (most accurate, most reflective of the subject in question, most useful to a particular researcher, etc.) for a given phenomenon or system in question. This was a distinction made early on by many of the theoretical biologists who helped found the study of systems. Living organisms obviously required some material form by which they existed. There was, however, no material cause which explained them being alive.

The need to explore all four causes supports the four quadrants of the Relational Theory model. How any or all of the quadrants relate to, or explain, the phenomena being studied, is a question to be further investigated.

As to the criteria for good systems research, in Chapter 2, Kineman sets out a number of clear expectations.

> We can take it as a requirement for a book about "systems research" that if one proposes an exemplary framework it should be *rigorous*, if not in some viable sense *scientific*; that is, it should respect ontological and epistemological principles and follow a defensible logic that is justified at some foundational level in mathematical philosophy, arguably the common

> language of science.…We want to be able to analyze the *organization* of a system in terms of relations between context (e.g., dispositions) and actualizations (e.g., dynamics). (Kineman, 2016b, p. 25)

In considering Kineman's explanation, the relations between context and actualizations create a *whole* or basis for the holon. The whole entails all four Aristotelian causal types in a natural relation; in doing so, it captures the essence of completeness through complementarity of potential existence and measurable behavior of a system. Kineman describes in great detail how the four-phase process of PAR corresponds to the four-quadrant model of R-Theory, incorporating Aristotle's four causes. Each quadrant of the model represents a separate holon, while the complete model represents yet another level of wholeness. All of this is necessary to create the general framework for a research study.

Chapter 2 offers researchers an inherently systemic, relational framework to understand frameworks through the thought provoking question, "What is the rationale for choosing the framework that will be used for the study, and what attributes (encoding and decoding) have been selected for the model (referencing Rosen's modeling relation) that will be constructed?" Each reseacher's rationale for his or her choice of method, whether relational (Rosen, 1991; Kineman, 2012) or one of the other systemic frameworks (von Bertalanffy, 1969; Gunderson & Holling, 2002), must be explicitly articulated in the study. The articulation of the framework contributes to the foundation for the research, thus providing the direction for next steps in the research process, problem structuring, research design, and modeling. The time spent developing the rationale for choosing a particular framework sets the stage for every step that follows in the course of the study.

Connecting Function to Context

Returning to Chapter 4, and the connections which bring about modeling, takes us to the focus of Chapter 3, "problem reflection" shown in the upper right quadrant in Fig. 8.1. In the spirit of Louis Sullivan's (1896) phrase, "form ever follows function," problem structuring and research design explore how systemic research is developed starting with describing the subject system and determining the research question(s) compelling the inquiry. The summary questions posed for that chapter are as follows:

- What is the purpose of the inquiry?
- Why is it important?
- Who will use the research findings?
- What is the scope of the research?
- What are the limitations and delimitations of this research?
- What contribution does it make?
- What are the implications of research that is inconclusive?
- How will emergent phenomena be handled?

A more specific issue for systems research offered by Edson and Klein (2016) is this:

> Describing your subject system is not synonymous with "defining a system" in the context of systems engineering, which details system specifications for the purposes of analysis, design, and development. In the context of systems research, describing your subject system entails explicitly explaining the context and interrelationships in which the system operates and the relevant boundaries you will examine within the scope of your research. (pp. 60–61)

There are several critical points in this paragraph to note. Many research methodologies, including variations of some described in this chapter, approach research from an engineering perspective; they determine a model or product to be created, and then establish a process for doing so. In engineering and similar research methodologies, predominantly deductive methods are applied. Assumptions arise from assessment of customer needs and requirements. A prototype is developed and tested (e.g., beta-testing) to see whether it works as designed or if it "breaks." When a system fails, troubleshooting or another systematic process is used for identifying the cause and problem solving. In traditional scientific research, an equivalent begins with hypotheses and works to build a model from that basis, testing the hypotheses to determine whether they are true, false, or null. In these approaches, systematic methods are used in bounded and controlled environments.

Challenges in engineering and scientific research entail environmental or contextual variables. Frequently, these are human dynamics that pose latent and nascent variables, many of which may be implicit but never made explicit in the research. These variables are sometimes expressed as emergent properties. In science and engineering, they are largely viewed as intractable; hence the strategy of defining boundaries for the purposes of controlled experiments and system specification for clients. In both cases, the audience has a level of confidence in the results because the expectations have been clearly defined. They can be viewed as closed systems. However, the relevance of the research results or utility product developed falls short precisely because they have been developed in isolation. In both cases, the adage "the whole is greater than the sum of its parts" is profound. Both have blind spots that result in issues like:

- A design, product, or development works in theory not in practice;
- Customer needs are not met because neither the customer nor the designer were aware (e.g. latent demand) or articulated these needs (or wants/desires) until after the product was delivered;
- Specialization prompts myopia and disorganization;
- Errors due to lack of synchronization (e.g., medical errors).

In a systems research study, researchers cannot include everything that might be conceivably connected in a model. Choices have to be made about the factors that are most relevant to the system in question, at the level of functioning being investigated. Concurrently, there has to be an understanding that the system does not exist or function in isolation. There are also relevant factors in the environment which co-determine the system in question. Those factors can, in turn, be described as the relevant environment for the system, as opposed to the environment referring to the rest of the universe. These choices depend somewhat on the priorities of the system studied and its role in its environment.

The elements chosen represent the characteristics which will be encoded into the model of the system being studied (i.e., the formal system from Rosen's modeling relation). Together, those characteristics and their relationships, within both the system and its relevant environment, will display behaviors that should at least be informative about the natural system in question. Ideally, they will display behavior as it changes and adapts over time, as actual systems do.

If a research study is problem-focused, the problem might appear to be obvious. If multiple stakeholders are involved, however, that assumption might quickly be contradicted. People may believe that they see or experience the same problem, but how they understand or define the problem can vary greatly. Verifying and reconciling these different perspectives can be painstaking, yet necessary for the research to be coherent.

When research is more topic-focused, questions about how to choose a system may seem even more complicated. If the universe is intimately connected (as it appears to be) then how do you know what to choose to study, and how can you be sure that it is a system? All of these questions are important, and none of them are arbitrary. Learning how to identify and study systems is something of a skill set unto itself.

If we begin with a problem focus, for example, we could choose a general topic such as increasing rates of crime in a particular city or region. To some degree, the first choices are much like any other research process. You need to decide how to define what you mean by crime (violent and nonviolent; all breaches of the law, including crossing streets without obeying signs, or only violations beyond a certain threshold, etc.). Determining the system involved, though, can be a different issue. When we consider all of the factors that are relevant to the problem, how do we decide to draw that first boundary? That initial boundary determination may draw distinctions that possibly fall outside or be more inclusive than distinctions others would assume or make. Again, these choices are neither absolute nor arbitrary. In many cases, it may take some time and effort for a most useful way of framing a system to emerge.

One way to approach this is by looking at previous efforts and studies to see what has not worked in the past. Natural scientists often look for gaps in understanding, or incomplete theories. For many social issues, there is no shortage of possibilities. Political decision-makers tend to work from simple, targeted assumptions for which limited funding can be directed, and which can be explained to the public in equally simplistic ways. In cases of crime, for instance, stronger laws, increased enforcement, and longer jail sentences are all familiar conservative responses, assuming that there should be direct, causal relationships (much like action and reaction in physics). They tend to focus on the individual as the problem. Typical liberal responses include increased assistance with education and training, counseling or psychotherapy, and so on. This perspective sees the context or situation as the problem.

The most appropriate boundary for a given study might include all of these or begin with a unique choice which redefines the system in question.

Similar questions can be posed about medical studies and public health, about cities and infrastructure, about ecosystems, and so on. As systems evolve, often so do their structure, functions, and boundaries. One of the challenges in understanding systems is simply identifying them as they exist, rather than as we wish to see them.

Determining first what has been tried and not worked can provide clues as to patterns of behavior. Widening the scope of possibilities until it seems unreasonable, and then narrowing back until the behavior of a system makes some new, logical sense, is another approach.

Traditional research approaches often focus on the development and testing of hypotheses. Those can be valuable, but that assumes a great deal of knowledge about the system or situation in advance. Otherwise, each narrow hypothesis becomes something of a "shot in the dark," hoping that correlations appear.

Charles Sanders Peirce (1839–1914) described the process of investigation somewhat differently than traditional science. This involved both induction and deduction, but also what he termed *abduction*. As explained by Burch (2014):

> Peirce increasingly came to understand his three types of logical inference as being phases or stages of the scientific method. For example, as Peirce came to extend and generalize his notion of abduction, abduction became defined as inference to and provisional acceptance of an explanatory hypothesis for the purpose of testing it. Abduction is not always inference to the best explanation, but it is always inference to some explanation or at least to something that clarifies or makes routine some information that has previously been "surprising," in the sense that we would not have routinely expected it, given our then-current state of knowledge. Deduction came to mean for Peirce the drawing of conclusions as to what observable phenomena should be expected if the hypothesis is correct. Induction came for him to mean the entire process of experimentation and interpretation performed in the service of hypothesis testing. (section 3, para. 10)

Peirce described abduction as a natural, ongoing process of conjecture that humans use on a regular basis. He understood the combination of the three processes (abduction, induction, and deduction) as the parts of the scientific method, in a continuous loop of learning.

Problem structuring also revisits questions of philosophy and ethics from Chapter 1. Topics and subjects for research are not just chosen randomly, whatever the sense of detachment by the researcher might be. There are reasons for selecting a research topic, even if it is only due to the funding that was available for it. Likewise, a topic might be chosen for its currency or popularity, and therefore have anticipated future value to the researcher. These are still not just arbitrary choices, and their influences will become important in the research itself.

In theory, scientific research might be one of many processes taken over by artificial intelligence machines someday. At present, though, research is an inherently human activity. Research begins from some sense of need or curiosity (by the researcher, the funder, an employer, customer or client, or someone else). This is generally described within the rationale for a study.

The design for a research study is a much more creative act than most students initially understand. It truly is a process of design. Likewise, both research questions (including hypotheses) and findings from analyses of data involve a significant amount of intuition and generation of emergent concepts. These raise additional questions about the role of the researcher in relation to the subject(s) of study, and the design and eventual process of the research.

Referring again to Rosen's (1991) modeling relation, an essential aspect of problem structuring is the selection of the attributes that will constitute the formal system (i.e., the model) which the research study will produce. What will be observed or measured and how will that take place? Who will be involved and what kinds of language or symbols will be used to capture and record data? Without knowing yet what the outcome of the model will be, from what will it be constructed?

Chapter 3 suggests both systematic and systemic ways to formulate competent descriptions of the subject system through problem structuring by focusing on questions such as: How have the problems been defined or research questions been developed? In what ways have these choices defined a whole system to be studied? What rationale was used and what are the necessary losses for the choices made? What is the research design for the study? Is it clear that the data selected to be gathered and analyzed will match not only the research design, but also the model that is being constructed (i.e., has coherence been established between them)?

In addition, as the choices made through the previous steps of grasping philosophy and frameworks are integrated with the understanding of the subject system, researchers have developed a strategy for investigating the subject system as they have defined it in a well-articulated research design. From an evaluative perspective, systems researchers must reconcile whether the methodological design (methodology, research process) and the methods (techniques and tools) chosen sufficiently fit, both systemically and systematically, the problem they have described. The more explicit systems researchers are in the description of the subject system and the research design, the chances improve for evaluators to fully comprehend the nature of the study and can evaluate it equitably.

Thinking Systemically

The tie between Chapters 3 and 4 takes us back to Chapter 1, the overarching philosophy of a study, and in this case, of systems. Philosophy of systems provides context and rationale for choosing systemic research approaches as opposed to others. Thinking systemically requires an understanding of the world as ever-changing and evolving. Heraclitus, in Plato's *Cratylus,* is known for his thesis on flux, captured in the translation, "You could never step in the same river twice" (Sedley, 2003, p. 104). This begins with systems philosophy, as addressed in Chapter 1 of this book. Even the physical objects that we see as absolutely solid and stable only appear that way at certain levels of organization. Rather than assuming that the natural state of the world is order and stability, it is more prudent to ask, what factors or forces or phenomena create stable patterns of order out of a universe which is inherently malleable?

This is formally expressed through concepts such as process philosophy (e.g., Whitehead, 1925/1967) but the same ideas date back far beyond traditional science. Even the most static and enduring entities are, at some level, repeating patterns of organization; elements held or recreated in formation from moment to moment. As such, the systems that we choose to study are never absolutely separate from the rest of the universe.

Living systems, most particularly, are intimately interdependent with their environments (Miller, 1978; Parent, 1996; Simms, 1999). People tend to see themselves as unique individuals, with separate personalities and other traits, often described in terms of the *soul* (an eternal identity). Physiologically, though, we are only minutes from extinction without an oxygen-rich environment in which to live, or only days without adequate water. Like all living creatures, we are intimately connected with our biosphere and with many other types of environments. We continue to adjust and adapt, physically and socially, as our bodies recreate themselves, and we create and recreate our relationships in the world.

A traditional approach to science assumed a great deal of stability and consistency in the universe (Sheldrake, 2005, 2011). That belief underlies the use of sampling in research and the legitimacy of generalizing from a sample to a population as a whole. That approach worked well enough for periods of time in physics, where general principles could be found that were not directly dependent upon time or location. It is much more difficult in terms of human social systems, for instance, where populations are harder to define and research results harder to verify. In Chapter 1, Debora Hammond (2016) offers this summary:

> Beginning with an emphasis on the holistic nature of reality and the importance of considering relationships, both among the components of a system and with the larger environment, a systems-oriented ontology highlights organization, interaction and interdependence, shifting from the atomistic and individualistic orientation of the mechanistic worldview to a more organic conception of nature and an appreciation of the patterns and processes of relationship. (p. 13)

There are both practical and ethical considerations in research. Through the process of learning, we change, as does the system in question. Everything that we touch in the world may have some impact, and that includes the studies that we conduct. For example, an observer impacts the observed, as has been acknowledged by the Hawthorne effect, Observer effect in IT (e.g.,"Heisenbug") and physics (related to, yet not to be confused with the Heisenberg Principle of Uncertainty), the Probe effect, and the Observer-expectancy effect (Weissenbacher, 2012.). One of the frameworks suggested by this book, PAR (Lewin, 1947; see also Argyris & Schön, 1978, 1989; Dewey, 1910, 1929; Freire, 1982; McIntyre, 2007), takes both practical and ethical issues into consideration. We enter into research understanding that we are studying dynamic processes in the midst of change. We can learn about them, and in some cases we can learn with them (with respect to human systems, at least). Ideally, we can learn many of the principles that cause their patterns of organization to remain stable at some levels over time. We also must consider our potential impact on the systems that we study, including the level of respect that we should observe for entities and phenomena that we did not create, and cannot re-create.

Werner Ulrich (2001) has written about boundary critique as a way of considering those choices. In Ulrich's (1999) tribute to C. West Churchman, he ponders Churchman's call for critical self-reflection in an essay about intellectual honesty as it relates to systems. Churchman's work was pivotal in Ulrich's (1988, 1999) understanding of systems. Churchman (1968) questioned his own work in saying, "How can we design improvement in large systems without understanding the whole system, and if the answer is that we cannot, how is it possible to understand the whole system" (p. 2)? Reflecting on this statement and considering the ethical implications of uncertainty in our decisions, Ulrich (1999) urges caution in his remark, "Uncertainty about the whole systems implications of our actions does not dispense us from moral responsibility" ("Intellectual Honesty," para. 4). To emphasize the importance of this responsibility, as a researcher may be influential and/or instrumental in effecting the subject system, Ulrich further quotes Churchman's statement, "the problem of systems improvement is the problem of the 'ethics of the whole system'" (as cited in Ulrich, 1999, "Intellectual Honesty," para. 4). In his reflection, Ulrich reveals a potential for benevolent bias in conducting ethical systems research—good intentions may not result in good systems outcomes. While uncertainty about understanding the whole system is an important consideration, it should not dissuade systems researchers from the work; however, the work should be ethically grounded. Systems researchers who check their assumptions develop an understanding that intending to do right (ethically) does not equate to being right (about the system).

Ulrich (1999) surmised that the message of systems,

> is not that in order to be rational we need to be omniscient, but rather, that we must learn to deal critically with the fact that we never are. What matters is not "knowing everything" about the system in question but understanding the reasons and possible implication of our inevitable lack of comprehensive knowledge. ("Intellectual Honesty," para. 4)

Bringing forward the questions outlined in Chapter 1, here are some of the first considerations for a researcher:

- What is my own relationship with the system I intend to study?
- What conceptual framework is guiding my choice of research topic?
- What assumptions, beliefs and values am I bringing to the research?
- What do I hope to learn?
- What impact will my research have on the system?
- What possible blind spots might I need to consider?

- How might I gain insights from the system itself?
- What might I learn from other disciplinary perspectives?
- What aspects of the system's environment might be relevant to my research?
- How will my research affect the larger environment (social or ecological) of the system?
- Whose interests does the research serve?
- Are there aspects of the system that might be negatively impacted by my research?
- What are my own motivations in doing the research?

As Debora Hammond (2016) summarizes her perspective in Chapter 1:

> Good systems research is broadly inclusive. It must be clear about the reasons for the boundaries it draws around the system under consideration, what is being left out, and possible consequences of those choices. Ultimately, good systems research supports the cultivation of wholesystems thinking. Good systems research seeks to nurture the health and integrity of the systems it serves and to manage the systemsthat structure our lives in ways that honor the needs and purposes of all participants in the system, as well as the larger environment within which that system functions. (p. 16)

Chapter 1 offers a path toward development of a systems perspective which is essential in creating a sound foundation for the research specifically by answering the question, "What philosophical and ethical principles are guiding the research and do they sufficiently reflect a systemic basis for the research?"

With Chapters 3 and 6 having already been discussed, the connection of competence of systems researchers closes the circle. The relationship between the description of the problem (even if theory development) and the expression of the research results depends largely on the competence of the researcher and the stance the researcher has taken relative to the researched. In evaluative terms, was the researcher able to adequately define the problem, design a research strategy, and report the outcomes in sufficiently systemic ways?

Role of the Researcher in Relation to the Researched

Chapter 7 returns us to the researcher as part of the research. As we think about designing and conducting research, what do we need to know? What skills or capacities are required for the kinds of research that have been described? Clearly, there are competencies beyond critical thinking skills that enable systems researchers to see and interpret systems in ways that are relevant to their stakeholders, whether they are scholars and/or practitioners.

These essential researcher competencies return us to Chapter 1 and the philosophical foundations of research. For people who need or choose to live in a Newtonian universe, asystemic approach will not fit a reductionist paradigm. A researcher needs a different stance to accommodate the fluidity and ambiguity of systemic research. Absolute answers, while offering the comfort of prediction that is accompanied by limited variables and formulas, are adequate for understanding only a small part of the world. As useful as mechanistic approaches have been in understanding the world, they are limited in utility for addressing complexity and its inherent uncertainty. Despite recognition of their limitations, reductionist approaches have been relied upon to formulate what is considered knowledge and to guide decision-making with wide ranging implications. Much of this acquisition of knowledge and decision-making is accomplished through attempts to control uncertainty, assuming that phenomena can largely be predicted if we acquire sufficient quantitative data and employ the "right" models. These quantitative approaches forego the "messiness" and variability of qualitative data. This is evident in the current drive to simplify complexity. Yet, it is in the mess that we are likely to find some of the most compelling insight into our world. Our goal is not to simplify complexity, but to accept that complexity is inherent in many systems. Our objective is to develop parsimonious explanations that will inform us.

In many ways, systems research is like a feedback loop, with the drive for prediction and reduction of uncertainty as a reinforcing loop. Reinforcing loops that remain unchecked cause disequilibrium in systems over time. For example, like a runaway train without brakes, a push to quantify human experience dehumanizes the experience. In the case of the train, the balancing loop is represented by the brakes. In human systems, especially systems research, the balancing loop is the judicious use of both quantitative and qualitative data. Through experience, researchers learn to develop competence in the negotiation balancing loops to manage uncertainty with reinforcing loops that drive the satisfaction of requirements for certainty.

In systems research it is wise to develop a level of comfort with uncertainty (e.g., understanding the inherent value of requisite variety, diversity, mutation, and adaptation) to avoid a trap of misrepresenting systems in efforts to reduce or simplify complexity. Negotiation of uncertainty calls for the capacity to reconcile seemingly incommensurables and the capability to leverage both quantitative and qualitative data with reason. All of this is done in service of parsimony. It is simplicity of the explanation, not simplification of complexity that matters. As Rosen (1991) observed, multiple perspectives cannot be reduced to one model, otherwise the model itself becomes a mechanical model and does not aptly reflect complexity of a system.

Learning about a system through a process of research also tends to change how we see and understand systems more generally. As described in Fig. 8.2, completing one research cycle ideally sets up the next cycle of research and learning. At that point, new questions, new insights, and new possibilities should be present. Understanding this as a natural cycle of learning rather than necessarily as a formality simply increases the capacities of those involved. Whether it is an individual researcher or a group or community, learning simply continues. Ultimately, Chapter 7 asks, “How has the researcher and the researched been transformed through the process of the investigation?” In evaluating research, we have come full circle through the PAR Holon organization of the book chapters shown in Fig. 8.1. So it is natural to ask, “What comes next in the iterative learning cycle of systems research” (see Fig. 2.2 Cycles in Action Research, O’Leary, 2004)?

What Is Good Enough? Concluding Thoughts

Systems research is an attempt to understand and describe phenomena as they exist in the universe. That requires understanding both the contexts and the relationships in which they exist. It means knowing that even the most stable entities only exist in relative states of change. That understanding requires different questions, for instance, asking not only about the external forces that cause change to an apparently stable system, but also about the internal forces and relationships which cause the system in the first place.

Returning to the example of the bicycle, more than a few children have learned hard lessons about change. A bicycle put away for the winter, if not protected and maintained, encounters often unexpected changes. Tires go flat, metal parts rust, seats weather and crack, and so on. No one did anything terrible to the bicycle. It was simply a result of the relationships between the bicycle and its environment.

Learning to see and ask about new relationships is another aspect of systems research. If investigating space travel, few people are likely to find correlations with a bicycle. They are apparent, though, simply from remembering that the first successful airplane was designed by two brothers (Orville and Wilbur Wright) who ran a bicycle shop (Smithsonian National Air and Space Museum, n.d.). Ways of thinking about the control of motion on the ground led to learning about controlling motion through the air, and so on. Bicycles did not “cause” spacecraft. The interconnected and evolving parts—trying new ideas, changing designs, creating new ways of thinking about machines, working to create a human-powered air machine like there was a human-powered machine for the ground—all can be seen as causes for spacecraft.

The importance of systemic ways of learning and understanding is as relevant for problem-solving as it is for the discovery of new, scientific theories. It is equally important for processes of design, in which we create models of things that do not yet exist—the inverse process of creating scientific models of what already exists.

In the context of PAR, specifically, good systems research is a conscious process of learning and change. That requires awareness of the researchers about their own knowledge and learning, as well as their expertise in the systems being investigated. It requires skill in research design, knowing that choices have to be made, and boundaries have to be drawn. What gets encoded into the model both creates and limits it. All of this has bearing on how well the model replicates the natural system that it seeks to describe.

In the context of this book, good systems research would cross over the fragmented disparities that have long characterized different beliefs about research. Being clear and specific are critical factors in research. To the degree that mathematical descriptions enhance clarity and specificity, they should be considered. Measurements of material causes, though, are not sufficient explanations for systems, by themselves. Equally, metaphorical descriptions of beliefs about systems, even if based upon reports by participants, cannot be solely relied upon as rigorous data.

Evaluation of research is fraught with complexity, so it is no surprise that evaluation of systems research is just as, if not more, complex. Beyond questions of whether the research is sufficiently systemic, are questions about the quality of analysis and the process. In evaluation we ask, "Does the research reflect integrated analysis with integrity in the process? These questions bring us back to the beginning of the research process and this guide.

One of the goals of this book sought to answer the question, "What distinguishes systems research from other forms of research?" To answer that question, researchers must go beyond systematic criteria to view inquiry through systemic lenses. This chapter also asked the question, "What is needed and what is good enough?" The previous seven chapters, concepts of systems research—philosophy, frameworks, problem structuring and research design, taking action, reporting results, and competencies—outlined some of what is needed. Certainly, as with any research, a disciplined approach is fundamental. The concepts presented correspond to the rigor expected of most scientific inquiry. However, as we have seen, scientific approaches are not sufficient to address systemic inquiry. Scientific methods, while useful complements to other approaches are insufficient in the inquiry of complex systems. This requires researchers undertaking systems research to go beyond traditional approaches and necessitates discerning application of the concepts explained in this guide. A final word by Whitehead (1925/1967) might best conclude this chapter:

> There are two methods for the purification of ideas. One of them is dispassionate observation by means of the bodily senses. But observation is selection. Accordingly, it is difficult to transcend a scheme of abstraction whose success is sufficiently wide. The other method is by comparing the various schemes of abstraction which are well founded in our various types of experience.…Faith in reason is the trust that the ultimate nature of things lies together in a harmony which excludes mere arbitrary mystery. The faith in the order of nature which has made possible the growth of science is a particular example of a deeper faith. It springs from direct inspection of the nature of things as disclosed in our own immediate present experience. There is no parting from your own shadow. To experience this faith is to know that our experience, dim and fragmentary as it is, yet sounds the utmost depths of reality: to know that detached details merely in order to be themselves demand that they should find themselves in a system of things: to know that this system includes the harmony of logical rationality, and the harmony of aesthetic achievement: to know that, while the harmony of logic lies upon the universe as an iron necessity, the aesthetic harmony stands before it as a living ideal moulding the general flux in its broken progress towards finer, subtler issues. (p. 18)

Writing this book has been a long journey from IFSR conversations in Linz, where the authors explored the question, "What is good systems research?" That exploration led to this book. Our intent is to help newcomers, graduate students, and seasoned researchers develop confidence in designing, conducting, and reporting systems research that meets the standards of rigor required by academia and organizations commissioning research studies, many of which are major research projects. The journey does not end here, as we realize this is an early attempt to put forward a proposition of what will render good systems research. Indeed, this does not mean we believe it is perfect. As Jack Ring (personal communication, February 25, 2016) stated, "System projects fail not from lack of requirements but from lack of designer humility. System design is a discovery process and learning happens when arrogance yields to humility." As systems researchers, we adopt the spirit of Ring's words by acknowledging that we put forth these propositions with humility. As our readers are learning, we will continue to learn from those who use and evaluate our work. We remain open to suggestions and ideas that will build upon these propositions. There are many excellent books and resources to help readers with the nitty gritty of systems research practices. Our aim was not to replicate or mimic those works, but provide different perspectives that can be used with any of those resources while enhancing the work to stand out as good systems research.

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Appendix: Systems Engineering

Systems Engineering is an engineering discipline whose responsibility is creating and executing an interdisciplinary process to ensure that the customer and stakeholder's needs are satisfied in a high quality, trustworthy, cost efficient and schedule compliant manner throughout a system's entire life cycle. This process is usually comprised of the following seven tasks: **S**tate the problem, **I**nvestigate alternatives, **M**odel the system, **I**ntegrate, **L**aunch the system, **A**ssess performance, and **R**e-evaluate. These functions can be summarized with the acronym SIMILAR: **S**tate, **I**nvestigate, **M**odel, **I**ntegrate, **L**aunch, **A**ssess and **R**e-evaluate (INCOSE, n.d.). This Systems Engineering Process is shown in Fig. 8.5. It is important to note that the Systems Engineering Process is not sequential. The functions are performed in a parallel and iterative manner.

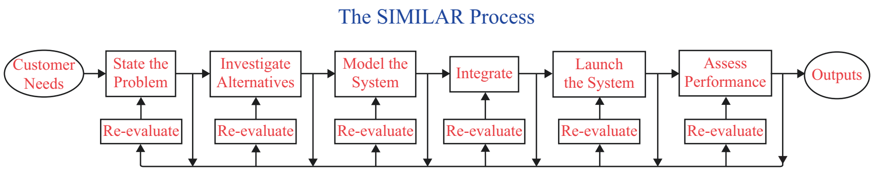

Fig. 8.5 The systems engineering process from Bahill and Gissing (1998)

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M.C. Edson et al. (eds.), *A Guide to Systems Research*, Translational Systems Sciences 10, DOI 10.1007/978-981-10-0263-2

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