An Introduction to General Systems Thinking

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Gerald M. Weinberg

A WILEY-INTERSCIENCE PUBLICATION
JOHN WILEY & SONS, New York • London • Sydney • Toronto

Boys and young men acquire readily the moral sentiments of their social milieu, whatever these sentiments may be. The boy who has been taught at home that it is wicked to swear, easily loses this belief when he finds that the schoolfellows whom he most admires are addicted to blasphemy.

Bertrand Russell

To Ross Ashby, Kenneth Boulding, and Anatol Rapoport, who got me addicted to blasphemy.

Library of Congress Cataloging in Publication Data

Weinberg, Gerald M
An introduction to general systems thinking.

(Wiley series on systems engineering and analysis)
"A Wiley-Interscience publication."
Includes bibliographical references and indexes.
1. System theory. I. Title.

Q295.W44 1975 003 74-26689
ISBN 0-471-92563-2

Printed in the United States of America

10 9 8 7

An Introduction to General Systems Thinking

Wiley Series on Systems Engineering and Analysis

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An Introduction to General Systems Thinking

SYSTEMS ENGINEERING AND ANALYSIS SERIES

In a society which is producing more people, more materials, more things, and more information than ever before, systems engineering is indispensable in meeting the challenge of complexity. This series of books is an attempt to bring together in a complementary as well as unified fashion the many specialties of the subject, such as modeling and simulation, computing, control, probability and statistics, optimization, reliability, and economics, and to emphasize the interrelationship between them.

The aim is to make the series as comprehensive as possible without dwelling on the myriad details of each specialty and at the same time to provide a broad basic framework on which to build these details. The design of these books will be fundamental in nature to meet the needs of students and engineers and to insure they remain of lasting interest and importance.

Preface

I found everything perfectly clear, and I really understood absolutely nothing. To understand is to change, to go beyond oneself. This reading did not change me.*†

This book is based on a course that over the years has changed the thinking of many people. In case you think that you are not the type of person to be changed by reading a book, let me quote for you some typical comments received in course evaluations.

An electrical engineer said of the course, "It made the many isolated subjects I had studied in college come together into a meaningful whole—and it also related them to my five years of on-the-job experience."

An archaeologist said, "I don't think I ever understood before the role of theory in my work, and just how powerful theory can be if you don't let it master you. When I dig now, I have always in my mind a perception of the site as a whole, and as a part of a larger whole, a living culture."

A composer said, "I probably couldn't demonstrate this to you exactly, but my recent compositions have been altered, definitely altered, and for the better, as a result of taking this course."

A computer systems analyst said, "I should have taken this course a dozen years ago. In three months I have learned more about what systems are than I knew previously. A problem that came up in my job and that would have caused me much grief was just erased with no effort because I was able to apply the Principle of Indifference. In another case, something that a few months ago would have slipped by unnoticed and gotten us into a lot of trouble was caught just because I

* It would be out of keeping with the informal tone of this book to clutter the pages with footnotes and references. We shall therefore confine all the other notes to the end of the book.

† Jean-Paul Sartre, *Search for a Method*. Translated by Hazel E. Barnes. New York: Vintage, 1968, pp. 17, 18. Sartre is referring to *Capital* and *German Ideology*, by Karl Marx.

almost unconsciously played some observer games with it. Under one of the new points of view, the problem was obvious. So was the solution."

But a computer programmer said, "I didn't learn anything in this course. It was a bunch of platitudes, no more than ordinary common sense. It was fun, but otherwise a waste of time."

You can't teach all of the people all of the time. We start with some promise of success and some warning that success is not guaranteed. To make things worse, books about thinking are a pox on the market—those who can't think write books about thinking. So beyond the several hundred testimonials running about 9 to 2 in favor of a significant change in thinking, what promise is there that this book can change your thinking and your understanding of the thoughts of others? Scholars learn to think in at least two distinct ways. One method begins with the mastery of the details of a discipline and then proceeds to transcend them. We speak of this transcendence in such approving terms as, "thinks physically," "knows anthropological theory," or "has mathematical maturity." What have we done in attaining this disciplinary maturity? For one thing, we have learned how to "approach" a problem—that is, what should be our first few thoughts.

This disciplinary method of teaching works well. First—obviously—it builds on the foundations of wisdom left by others and conserves the effort of retracing their steps. Second—and in our fragmented society, not so obvious—the disciplinarian confines himself to a rather small range of "problems," a range in which he is fairly confident of his ability to get results. A successful disciplinarian knows what problems to avoid.

But what of problems that refuse to be avoided? What of the depletion of our natural resources by an ever-increasing population in an ever-more-wasteful economy? What of expanding technology, usually the obedient servant but occasionally the terrible master? What of grisly wars and impoverished peace? What of death, and what of me, dying?

Such problems fall outside any discipline. Many lesser problems too come supplied with no familiar label. This book attempts to teach an approach to thinking when the labels are missing, or misleading. This approach *precedes* the disciplinary studies—and sometimes bypasses them, or integrates them. We call this way of thinking and teaching the general systems approach.

The general systems approach is not *my* invention. Many people have made original contributions to the general systems approach, but

I am not among them. Why, then, do I write this book? Only because, through a dozen years of attempting to teach general systems thinking I have found that none of the "introductory" books make it accessible to a truly general audience.

My role, consequently, is to integrate a mass of material into an introductory form. I have tried to gather insights both from general systems theorists and from disciplinarians, to arrange them in a consistent and helpful order, and to translate them into a simpler and more general language so that they become common property.

There is, then, a double meaning to the word "general" in the title: *the most generally applicable insights made available to the most general audience possible.*

By elevating particular disciplinary insights to a general framework and language, we make some ideas of each discipline available for the use of all. If these ideas have been well chosen to have general application, then this approach should yield for the disciplinarian a certain economy of thought—he need not retrace steps taken in other disciplines. This book, then, is not for "systems specialists," but for systems generalists.

Who are those "generalists"? Certainly they include—and have included in my courses over the years—almost anybody who uses his or her brain to make a better living, or to make living better. I have had managers and other organizational leaders, social and biological scientists, computer systems designers, many engineers, and a whole host of college undergraduates in all fields. I have had anthropologists and actors, businessmen and biologists, cartographers and cab drivers, designers and dilettantes, electrical engineers and Egyptologists, French majors and farmers—we need not continue the exercise.

Few of these people had mathematical training much beyond high-school algebra, and some not even that. The treatment of mathematical subjects in the book is geared to this level because it is the level on which most people—most educated people—happen to find themselves. A control systems engineer who reviewed this book felt a danger that, should his students read it "they would not want to study their calculus and differential equations."

But read what a chemistry student said: "The follow-on for this course for me is a course in differential equations. I always dreaded the thought after finishing calculus, and since it wasn't *required,* I just kept putting it off. But I knew I needed it, vaguely, and now I know why I need it *precisely.* More than that, I've lost my fear—they can't touch me now that I know what it's about." Or a sophomore biologist: "I haven't taken any math since high-school algebra. That's really stupid for a biologist, but until this general systems course I never knew that. I'll start calculus next semester, if they'll let me."

Can these claims be true? Leaf through the book, and you will find a variety of graphs, diagrams, symbols, and even equations. But they are not there to mystify. Just *because* ordinary people are so often alienated from science and technology by such devices, a book on general systems thinking must be designed to lift the veil off their mysteries.

The appropriate mathematical symbolism will first be justified, then explained, as needed. Contrary to popular belief, scientists use mathematics to make things clearer, not more obscure. I intend to use math only that way, so, if you find the symbolism unclear, try once more. If it is still unclear, give up, blame it on me, and proceed. You won't miss too much.

Not all sciences confound with mathematical symbols. Ordinary words do quite nicely—especially if you don't really know what you are talking about. My computer experiences have made me aware that people often have but a foggy idea of what they are saying. Through translating thoughts into computer programs, I have learned many fog-clearing techniques. These techniques would have been impossible without the knowledge gained from computing, which is why so few of them are understood by older scientists—and systems theorists. This book will not teach you to program computers, but it will teach you to think the way a computer programmer should.

And speaking of fog, let us leave no illusions about the clarity of my own thoughts. Over the years of writing, entire sections of this book have been scrapped as the mist has been dispelled. Moreover, I am not afraid to employ slight inaccuracies to make the lessons more forceful and therefore more memorable. In other words, I choose vigor over rigor.

So do not take this book too seriously. It is not a bible, nor a proof, nor even a cohesive argument. It is, indeed, *my* first few thoughts, a collection of hints, nudges, pushes, and sometimes shoves, which aim to assist *your* first few thoughts on any "systems" problem. As another of my students said, "I feel that this course has made me twice as good a (computer) systems designer, but I *know* it has made me ten times as good a thinker." I hope it will do as much for you. It may do more.

GERALD M. WEINBERG

June 1974

How To Use This Book

In manuscript form, this book has been used in several ways, but particularly for individual or class use. Although the reader will undoubtedly discover his or her own ways of using it, some notes on how the author has seen it used and planned its use might be in order.

For individual use, the best approach is probably just to read it straight through, ignoring all the bibliographic material. The Questions for Further Research at the end of each chapter should probably be read as part of the text, to give an impression of the scope of problems to which the chapter materials might apply. Should some problem or quotation strike you as particularly intriguing, make note of it and then use the references to take it up later. Since the book is intended to introduce you to new ways of thinking, many quotations and references have been given—not to lend a patina of scholarship, but to give you numerous pointers toward other paths to learning.

Not all of the references represent *good* examples, so further assistance is given through the medium of the Recommended and Suggested Readings at the end of each chapter. The fundamental difference between "recommended" and "suggested" is that over the years I have found it imprudent to "recommend" that someone read an entire book. Either they don't do it, or they do and have a rather different perception than mine of its worth. In the latter case, I have made an enemy; in the former, I have made someone wish to avoid me. But do read some of the suggested books anyway.

For classroom use, there is a great variety of options. For a typical university curriculum, the seven chapters may be assigned one roughly every other week, with intermediate weeks used for the recommended readings. This is the scheme we use when we are dealing with a "mixed" audience—that is, with students from a variety of disciplines all in one class. When the class is more homogeneous, more specialized readings may be substituted. This approach has been used, to our knowledge, at least in management science, computer science, and behavioral science.

The text itself is suitable for any "level," from sophomores on up, with the adjustment being made by assignment of differing amounts of supplementary reading and questions for further research. The research questions themselves are usually suitable for either a short essay or a term paper. In higher-level courses, we have students prepare one or more of these questions for class presentation. For those students without mathematical background, the notational exercises are highly recommended.

The very flexibility of this book and generality of its material make it difficult to set in a university curriculum. "In what department does it belong, really?" "At what level student is it aimed?" These questions, so frequently asked of me, might be symptomatic of the excessive categorization of our society—breaking down knowledge into disciplinary fiefdoms and people into age-graded human waves passing through an education factory. But those who ask are often sincere in their attempt to cut through the present structure and obtain something better, and we should try to give them a helpful answer.

With regard to "where," a course or sequence in the general systems approach might be found in any department where there is a willing instructor and a cooperative chairman. In some places, cross listing of a course is the traditional way of handling such hot potatoes; in others, provision already exists for all-university, or at least all-division courses. Quite often, the Philosophy Department would be an appropriate place, except that our ex-resident philosopher, Virg Dykstra, always taught us that there shouldn't be a Philosophy Department—just a philosopher in every department. So perhaps there ought to be a general systems course in every department, taught by its philosopher. Alternatively, the book can certainly be supplementary reading in a variety of courses.

With regard to "who" or "when," I can be more specific if my own personal prejudices may be allowed to creep out. I have taught this material to sophomores, juniors, seniors, beginning and advanced graduate students, as well as to those long out of formal education. For some reason, the most exciting times were with seniors or those long out of school. The seniors seem to be looking for a way of integrating a befuddling mass of four years' worth of factual material into something they can actually *use.* Although at first glance the idea of this material being *useful* might seem hilarious, more than a few students have returned or written to tell me that this was the most useful course they took in four years of college. I hope that speaks well for the course and not badly for the college.

Perhaps this practicality is what makes the course take so well with working people, whose consistent reaction is to bring tales to class of how they applied, or should have applied, some general systems law or other to their daily labors. On the other hand, beginning graduate students seem too often obsessed with achieving the maximum specialization possible in the minimum time, while sophomores just want a few specifics on which to hang their generalities. But, naturally, people don't fall so neatly into these class categories, and I'd hate to think of the learning I would have missed by excluding certain graduate students and sophomores from my classes.

Acknowledgments

This book is the work of many people, work that merely happens to be assembled by one. First are the students who found themselves used as guinea pigs over the years and didn't squeal too much except when it really hurt. Second are the coteachers who used and/or contributed this material in working with me: Ken Boulding, who let me help out in his Senior Honors course at Michigan; Jim Greenwood, who took over for me at the IBM Systems Research Institute in New York; and Don Gause, who shares the teaching with me in the Human Sciences and Technology group at the State University of New York at Binghamton. Third are all those who taught me directly, but especially those to whom this volume is dedicated, Ken Boulding, Anatol Rapoport, and Ross Ashby. Fourth are all those whose material has been so liberally borrowed by me for the book, and may anyone who has not received proper credit please forgive me enough to let me know of my oversight. Fifth are the ever-so-many people who have contributed editorial work over the ever-so-many years this work has been in progress: especially Sheila Abend and Shanna and Mike McGoff. Finally, and in the place of greatest gratitude, are the two who read and ripped to shreds every word and diagram so as to convert a lumpy oatmeal pudding into what I hope is more like a wedding cake: Joan Kaufmann and Dani Weinberg.

Other Books by Gerald M. Weinberg

1961 *Computer Programming Fundamentals* (WITH H. D. LEEDS) (MCGRAW-HILL)

1966 *PL/I Programming Primer* (MCGRAW-HILL)

1970 *Computer Programming Fundamentals, Based on the IBM System/360* (WITH H. D. LEEDS) (MCGRAW-HILL)

1970 *PL/I Programming—A Manual of Style* (MCGRAW-HILL)

1971 *The Psychology of Computer Programming* (VAN NOSTRAND REINHOLD)

1973 *Structured Programming in PL/C* (WITH N. F. YASUKAWA AND R. MARCUS) (WILEY)

1973 *Teacher's Guide to Structured Programming in PL/C* (WITH N. F. YASUKAW AND R. MARCUS) (WILEY)

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