Annotated bibliography on research methodologies

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1 Introduction

This annotated bibliography includes a small sample of sources on various aspects of research methodology from diverse disciplines that influence research on artificial intelligence techniques in engineering design analysis and manufacturing (AIEDAM). Some of these sources are extended edited volumes containing many relevant contributions and pointing to additional references. These volumes are marked by a preceding bullet (•). The bibliography is not comprehensive; it covers only several important subjects and in each subject, it lists several representative contributions ordered chronologically. The selected list of subjects includes:

(1) *Philosophy.* This section is very short. It is very easy to locate many (or even too many) additional references from this category.

(2) *AI research methodology.* This section contains references on issues related to AI research methodology. Many additional references on the foundation of AI appear in (Partridge and Wilks, 1990).
This section also includes a subsection with several example projects that exemplify different methodological issues and a subsection describing the evolution of ideas in one particular expert system "programme" that were informed by research and practical experience.

(3) *Verification and validation of expert systems.* This topic is treated separately from AI research methodology due to the volume of publications it has produced. This topic bears significant relevance to the perception of AI programs as theories since the verification and validation of these programs *is considered* as their evaluation as theories. For AIEDAM research, being more "applied" than AI, these verification and validation techniques may involve greater emphasis on practical testing of programs.
By and large, the research on this subject focused on rule-based expert systems although, some work has been done on propositional and first-order predicate logic knowl-

edge representation. It is interesting to mention the extent at which researchers in this area use terminology for evaluation criteria. A partial list includes: accuracy, adaptability, adequacy, appeal, availability, breadth, completeness, consistency, conciseness, coverage, depth, effectiveness, efficiency, extent, extensibility, face, validity, friendliness, generality, granularity, incrementalism, modifiability, naturalness, operational validity, portability, precision, realism, reliability, resolution, robustness, sensitivity, scope, soundness, suitability, technical validity, testability, transparency, Turing test, understandability, usefulness, validity, and wholeness.

(4) *Machine learning.* This topic is treated separately from AI research due to the effort spent by researchers to elucidate the issues related to the evaluation of machine learning (ML) projects and the relation between theoretical, empirical, and practical research. An intrinsic property of this discipline accounts for some of this activity: ML programs must be tested even in basic research to show improvement of performance due to learning; therefore, evaluation becomes inherently central to ML. This section is particularly instructive since the importance of ML in AI and AIEDAM is growing constantly.

(5) *Social science.* This section demonstrates that research methodology involves not only discussions on worldviews but also analyzes of the detailed techniques of research methods within each worldview. Since AIEDAM research gains insight from engineers and its results might have to be evaluated in practical settings, the importance of social science research methods grows.
Additional references on this topic appear in the practitioner perspective section.

(6) *Social science and computing.* This section discusses the interaction between social science and computing as it manifests in studying the interaction between users and computer tools. The section contains representative studies from computer-supported cooperative work (CSCW), participatory design of computer systems (PD), development of human-computer interaction (HCI)[1] tools and graphical user interfaces (GUI), and the utilization of AI tools in various settings including research. All these issues have some overlap with AIEDAM research.

(7) *Information systems research and development.* This section deals with methods for developing information systems for practice. It documents views on developing systems with users and on the study of such systems in traditional as well as case-study methods. Information systems research and development are highly relevant to AIEDAM research if the latter is expected to have any practical impact.

(8) *Practitioners perspective.* The section deals with practitioners perspective of research methodology. It provides a sample of studies illustrating the multiplicity of approaches to doing research in various disciplines. These studies are almost always prefaced with a critique of the traditional scientific method.

(9) *Engineering design and manufacturing research.* This section contains several references on methods for doing research in engineering design and manufacturing (with or without AI).

[1] Notice the acronym CHI of the conference series as opposed to HCI; is this accidental? or does it reflect different worldviews?

2 Philosophy

(Kuhn, 1962) This book is a classic critique of the positivist view of scientific progress. This book illustrates how science progresses through periods of "normal science" when scientists employ various types of criteria for judging theories' and how paradigms shift through revolutions triggered by anomalies that cannot be accounted for by any rationalization.

(Popper, 1965) This book discusses how progress in science occurs through raising conjectures and putting them to stringent tests by trying to refute them. While no confirmation of hypotheses is possible, a hypothesis is better than the other if it allows for better chances of being refuted.

(Lakatos, 1968) This paper suggests that science is organized in research programmes: a structure including a hard core that is not questioned and auxiliary hypotheses that guard it from negative evidence. Acknowledging that no data can confirm or refute a theory, scientists should adhere to some normative rules when revising auxiliary hypotheses.

(Habermas, 1971) This book provides a critique of positivism through a study of the historical development of ideas that led to contemporary positivism. The book does not argue against science, but against "scientism:" The view that equates *all* knowledge with science.

(Toulmin, 1972) This book argues for the necessity to bring philosophy and science together for a reappraisal of epistemology and methodology. Philosophy is to be a historical, empirical, and pragmatic enterprise that should focus on issues such as conceptual change in the sciences and human thought.

(Weimer, 1979) This book develops a meta-theory of science in which positivism and logical empiricism and called justificationism and opinions such as those of Popper and Kuhn are termed non-justificationism. The book criticizes justificationist theories of science and uses the meta-theory to explain the differences between positions of different contemporary non-justificatinists positions.

(Knorr-Cetina, 1981) This book provides a constructivist view of science. It uses several metaphors of a scientist to study the way in which social processes make up for the lack of any rational way for advancing science.

(Bunge, 1983) A part of an eight-book treatise on philosophy, this book provides a systems science perspective on epistemology and research methodology. It presents a serious study of scientific realism.

• (Kourany, 1987) This book is an excellent collection of contributions by leading philosophers on the issues central to scientific inquiry: the nature of explanations, the validation of knowledge, and the historical development of knowledge.

• (Pickering, 1992) This book provides a constructivist view of science or a perspective of science as practice. The first part of the book presents positions on the practice of science and the second part contains discussions on the differences between science-as-practice and the sociology of scientific knowledge.

3 AI research methodology

(Newell and Simon, 1976) This paper discusses the hard core of AI: the physical symbol system hypothesis. The hypothesis states that a physical symbol system has the necessary and sufficient conditions to act intelligently.

(McDermott, 1981) This paper illustrates how simple practices of AI such as naming procedures and data structures, hinder progress and cause confusion about the merit of research.

• (Haugeland, 1981) This book contains a collection of papers on the philosophy and objectives of cognitive science.

(Nilsson, 1982) This paper presents AI as a branch of computer science that similar to the other branches is concerned with representational formalisms: The one that underlies AI is propositional languages. The paper argues that beside few topics, AI is concerned with the formalisms themselves and not their content. It also argues against including "peripheral" processes, such as vision, in AI.

(Newell, 1983) This chapter describes the historical evolution of some of the key issues in AI research over the past 40 years and through them the relations between AI and its neighboring disciplines.

• (Yazdani and Narayanan, 1984) This edited volume contains, among other topics, sections on AI methodology and the philosophical implications of AI. The nature of programs as theories and their testing is a principal issue.

(McDermott et al, 1985) This paper summarizes the views of several researchers on the status of AI, the expectations of its practical utility within the public, the role of researchers and the media in creating these expectations, and other similar issues.

(Hall and Kibler, 1985) Starting from several positions on AI research, the paper arrives at a classification of five approaches: performance, constructive, formal, speculative and empirical, to doing AI research with some exemplars projects in each class. The paper argues that researchers aught to make their commitment to a particular approach clear in their research reports.

• (Gilbert and Heath, 1985) This edited volume discusses the potential interaction between AI and sociology. The views range from dismissing the computational metaphor of intelligence to thinking that AI methods, in particular building programs and testing them, may provide tools for studying problems in sociology.

(Sharkey and Brown, 1986) This paper argues that significant benefit can result from a cooperation between AI and cognitive science for explaining human cognition. Without such cooperation, AI claims to mimic intelligence may be faulty. Schema theory and spreading activation network theory are examples of such successful cooperation.

(Partridge, 1986) This paper discusses the differences between software engineering and AI system building. Consequently, different approaches are necessary for these two activities. Nevertheless, independent of any approach for developing AI systems, such development is likely to pose software problems more significant than those resulting from developing regular software.

(Partridge, 1987) This note reports on a workshop on the foundation of AI. The presentations at this workshop have been collected into (Partridge and Wilks, 1990).

(Schank, 1987) This paper defines the primary objective of AI as building an intelligent machine. Ten broad classes of problems are central to AI research. Two routes to performing research are application and scientific.

(Cohen and Howe, 1988) This paper argues that evaluation is a means of progress for AI research. It lists different criteria for evaluating research problems, methods, implementations, and experiments and their results.

• (Lehner and Adelman, 1989) This special issue on perspectives on knowledge engineering samples papers from different, sometimes contrasting, perspectives including: classical AI, psychology-based, knowledge engineering, decision science, software engineering, empirical, and philosophical.

(Bundy and Ohlsson, 1990) This chapter contains the debate that appeared in AISB Quarterly in 1984 between an AI researcher and a psychologist, mainly on the relation between AI programs and theories. Much of the debate revolved around the clarification of different terms from the perspectives of the two disciplines.

(Dietrich, 1990) This paper presents a strong critique of AI methodology by discussing two errors in the AI programme: the assumption that adopting Turing thesis helps AI find the right programs to mimic intelligence and the assumption that the theory of computation can lead to a theory of intelligence.

• (Partridge and Wilks, 1990) This edited volume is a comprehensive source, including a significant bibliography, on the foundations of AI. The topics discussed include various methodological questions such as the role of representations and programs in research and the limitations of AI technology.

(Wegner, 1991) This paper discusses the tension between the formalist, realist, and idealist paradigms as reflected in four topics in computer science: modes and paradigms of computation, type versus value, and computational versus software complexity.

(West and Travis, 1991) Starting with describing the sensitivity of AI researchers to criticism, this paper discusses the role of metaphors in science (a perspective or model; in contrast, a worldview can include several metaphors) and provide a strong critique of the computational metaphor of AI.

(Sloane, 1991) This paper describes a failure of an AI project due to a methodological deficiency: the use of participatory design to implement a hierarchical control that clearly will undermine the participation of some of its developers in future decision making.

(Cohen, 1991) This paper surveys papers from the 8th AAAI conference to reveal two trends in AI research: model centered (or more theoretical) and system centered (or more empirical). The paper argues for a combined approach. The two trends and the combined approach are referred to as different methodologies.

(Churchill and Walsh, 1991) This paper criticizes the arguments in (Cohen, 1991) and offers a comparable, but modest analysis of European AI research.

(McKevitt and Partridge, 1991) This paper proposes a software engineering approach that may address the difficult issues in AI research: the poor description and definition of AI problems and the poor testing of hypotheses. The paper also discusses the role of AI programs as theories.

3.1 Several examples

(Ritchie and Hanna, 1984) This paper demonstrates through a detailed case study that AI programs may not be able to serve as theories. It is almost impossible to clearly and accurately state what AI programs do and why. It is equally hard, therefore, to replicate such programs.

(Lenat and Brown, 1984) This paper responses to the critique in (Ritchie and Hanna, 1984). It explains why AM appeared to work and why its *adhoc*ness may be its source of power.

(Niwa et al, 1984) This paper describes a study comparing between knowledge representation schemes. Years later, similar ideas have been incorporated in the Sisyphus project of the knowledge acquisition community (Linster, 1992).

(Pople, 1985) This paper reflects upon a decade of research experience with building expert diagnosis systems. It argues that the development of real expert systems is empirical, requiring iterating between observations, modeling, testing in real context with experts, and model revision.

(Clancey, 1986) This paper reflects upon six year of developing a series of large systems and contains some methodological guidelines. Central to the experience is that the development of a sequence of systems was inspiring and lead to major changes in understanding the underlying problem.

(Arbib and Hesse, 1986) This book provides an example of how AI and philosophical perspectives can interact to refine both. The results is an integrated perspective of human knowledge — certainly not a definite solution, but a stimulating one.

(Cohen and Howe, 1989) This paper describes the role of evaluation in guiding AI research by reflecting upon three case studies of design systems. The paper makes a distinction between empirical and applied AI research.

3.2 The evolution of one expert system "programme"

(McDermott, 1982) This paper describes the R1 system for configuring DEC's VAX computers. The paper describes the task, the details of the system and its implementation, and its successful use in configuring computer orders based on one year perspective.

(Bachant and McDermott, 1984) This paper discusses the development of R1 in its four years of operation in terms of the knowledge it had accumulated, the evolution of the development process, the difficulties in adding even similar knowledge into the knowledge base, and some of the perspectives that have changed with regard to the system over the years.

(McDermott, 1986; McDermott, 1988) These papers suggest how better expert systems could be built using the experience from earlier projects. The focus of projects should be on better understanding of problems-solving methods and building knowledge acquisition tools that can assist in the acquisition and utilization of knowledge for these methods.

(McDermott, 1990) This paper argues that the "isolationist" approach of AI hampered its objective to ease the process of software programming.

(Marques et al, 1992) This paper argues that embedding tools that users can use to create useful programs and correct their performance can ease the difficulties inherent to users-programmers interaction. The paper describes three tools that are aimed at supporting such a process.

(McDermott, 1994) This seminar criticizes past ML and knowledge acquisition approaches to build AI systems that can function well in the changing environment of a workplace. It offers an alternative that may improve the situation.

4 Verification and validation of expert systems

(Gevarter, 1987) This paper discusses the principles of evaluating expert system building tools. The paper also conducts such evaluation of many commercially available tools. The evaluation is based on their built-in functionality, not on their proven merit in practice.

(Marcot, 1987) This paper describes how expert systems need to be developed, including their evaluation through a long set of criteria.

(Bundy, 1987; Bundy, 1988) These papers argue that a key to the making of more reliable expert systems is through developing a sound theoretical foundation for making knowledge engineering an engineering science. The tool of mathematical logic is offered as the proper sound foundation.

(Agarwal and Tanniru, 1990) This paper describes an approach for the development of expert systems that is driven by the need to transfer expertise to non-expert users. This situation differs from the needs driving the development of regular information systems through prototyping.

(Chu and Elam, 1990) This paper demonstrates that the utilization of computer tools can restrict decision making as compared to making decisions without computer aids.

• (Ayel and Laurent, 1991) This edited volume includes chapters on general issues of verification and validation of expert systems including mainly an elaboration on ensuring the logical structure of expert systems.

(Adelman, 1991) This papers provides an excellent tutorial overview on three methods for evaluating expert systems: controlled experiments, quasi-experiments, and case studies; and their differing characteristics with respect to the reliability and validity of expert systems.

• (Gupta, 1991) This edited volume contains many references on: the verification and validation of expert systems, methods for developing expert systems to promote their quality, and case studies of expert systems development. This collection contains only previously published, widely referenced papers.

(Preece and Moseley, 1992) This paper describes a case study of evaluating three approaches to expert system development by solving the same problem with these approaches and comparing the development and evaluation process of all three.

(Preece et al, 1992) This paper provides a review of several programs for the syntactic verification of expert systems.

(Reich, 1995) This paper discusses the measurement of knowledge in expert systems, a fundamental issue in the development and evaluation of such systems. The paper discusses this evaluation through several complementary perspectives.

(Guida and Mauri, 1993) This paper argues that present evaluations of expert systems are poor, partial, and not easily applicable. The paper attempts to define the ingredients of evaluation more precisely and provide a framework for evaluation. The paper leaves out the evaluation of the expert system in a practical setting.

(Prerau et al, 1993) This paper reports on the evaluation of four different expert systems. The relations between the evaluation and the expert systems features are highlighted.

(Nazareth and Kennedy, 1993) This paper provides a historical survey of the development of research in verification and validation of expert systems. The paper discusses an agenda for future research that is hypothesized to lead such research towards becoming a mature scientific discipline.

(Adelman et al, 1994) This paper reviews different evaluation methods for assessing the technical, empirical, and subjective facets of expert systems. Such an evaluation is required to test whether a system meets sponsors and users criteria and expectations.

5 Machine learning

(Angluin and Smith, 1983) This paper reviews theories of inductive inference and their relation to algorithms and their implementations, including evaluation criteria of inductive inference methods. The most fundamental problem is the gap between abstract theories and concrete algorithms.

(Kibler and Langley, 1988) This paper explains how ML techniques are to be evaluated experimentally. The paper outlines the details of: which dependent variables are important, comparing between methods, changing domain characteristics, and designing experiments.

(Amsterdam, 1988) This paper criticizes formal and empirical models of learning from a psychological and ontological considerations. The critical argument is that learning a single concept is an under representative case of learning a web of concepts which is necessary for modeling learning.

(Weiss and Kapouleas, 1989) This paper discusses an empirical evaluation of several ML classification methods, including a description and justification of the method of comparison.

(Mingers, 1989b; Mingers, 1989a) These papers describe empirical studies of two critical aspects of decision tree induction methods: the selection of splitting attribute and the pruning of trees. The methods and criteria of evaluation are discussed in detail.

(Buntine, 1989) This paper criticizes the Valiant model of learning for being too conservative and inapplicable to model practical implementations. The deficiencies of the model are discusses and an alternative Bayesian model is proposed.

(Buntine, 1990) This paper criticizes several myths held by ML researchers concerning learning classification rules. It discusses them from a Bayesian perspective and raises issues that should be addressed by researchers both theoretically and experimentally.

(Turney, 1991) This paper identifies the issue of bias as the one preventing from ML theories to be relevant to practice. The paper proposes a way to incorporate bias in theories that may improve on the Bayesian approach of (Buntine, 1989).

• (Thrun et al, 1991) This edited report summarizes the performance of many ML programs on a very simple learning task. Note that the task is *a priori* more favorable for some of the programs.

(Segre et al, 1991) This paper analyzes several cases of experimental evaluation of explanation-based learning (EBL) programs and reveals methodological problems. These problems may affect the conclusions obtained from these experiments.

• (Linster, 1992) This edited volume contains the solution of several research groups to the same knowledge acquisition problems. It represents an attempt to improve the evaluation of different knowledge acquisition approaches.

(Pazzani and Sarrett, 1992) This paper presents an average, rather than worst, case analysis of some simple ML programs in an attempt to better tie the predictions of ML theories and practical results.

6 Social science

(Blumberg and Pringle, 1983) This paper criticizes empirical manipulation as the solution to the "how to" do research in the social sciences whose nature contrasts the non-reactive, non-evolutionary, and closed nature of the natural sciences. The paper reviews an example of an action research project that failed due to the use of controlled experiments. Subsequently, the paper discusses the particular needs that action researchers have in doing their research.

(Shvyrkov, 1987; Shvyrkov and Persidsky, 1991) These papers argue that the basic hypothesis underlying the use of statistics is the homogeneity of the empirical data set. The methods to test this property are purely subjective. These papers discuss some contradictions that this raises and propose a solution.

(Smith, 1987) This paper shows how qualitative and quantitative analyzes could be combined to support both better understanding (through qualitative analyzes) and better causal explanations (through quantitative analyzes) of social phenomena.

(Aldag and Stearns, 1988) This paper studies several journals in the organizational science to analyze the kind of methods used in management research. A variety of methods is detected including: meta-analysis, sampling, qualitative studies, studying managerial decision making, causal modeling, and historical analysis of events.

(Maso, 1989) This paper describes the conditions under which research goals must be reformulated during research. This should be done not only in qualitative research, such as participant observation, but also in other types of research as well.

(Bloombaum, 1991) This paper demonstrates how a flawed research conclusion could have been avoided by employing a more careful experimental design. The critical relation between theory, experimental design, data collection, and its analysis are therefore revealed.

(Bailey, 1992) This paper claims that social scientists are forced to adopt the positivists methodology that is associated with mature science while abandoning case study approaches. The paper suggests that instead of such move, the criteria of each of the methodologies should be developed to ensure scientific rigor.

(Brinberg et al, 1992) This paper shows that a Bayesian analysis can extract useful information about a hypothesis from a series of confounded and un-confounded experiments.

7 Social science and computing

(Gallupe et al, 1988) This paper presents results that the use of GDSS significantly improves decision quality of groups.

(Nunamaker et al, 1988) This paper analyzes observations of many groups using GDSS, to conclude that on some dimensions using GDSS was useful to the groups using it.

(Pinsonneault and Kraemer, 1990) This paper argues that empirical findings in this area are often contradictory and inconsistent. This forces great care in developing and testing facilities for electronic meetings. The paper describes an empirical study that demonstrates that the benefits from GDSS are different than from GCSS (Group Communication Support Systems).

(Gray et al, 1990) Starting by reviewing the discrepancies between empirical findings on electronic meeting, this paper develops a classification of experiments to allow for a better comparison of experiments. It is hoped that comparing between similar experiments will improve the analysis and development of new tools.

• (Carroll, 1991) This book discusses the role of psychological theories in the design of human-computer interactions. The relation between an interdisciplinary science borrowing from several basic sciences is discussed, including its impact on the two sciences. Doing science in context is one of the themes of this book.

(Tatzlaff and Mack, 1991) This chapter summarizes positions on methods that may lead to more practically relevant HCI research.

(Pylyshyn, 1991) This paper provides an acknowledgment by a classical cognitive scientist of the incompetence of psychological research to contribute to the development of better HCI systems.

• (Greenberg, 1991) This book contains various perspective of doing CSCW research including studying groups without computers as a necessary "control" information. The book discusses traditional as well as participatory design approaches to developing CSCW tools.

• (Bowers and Benford, 1991) This edited volume contains discussions on fundamental issues in CSCW. The focus of CSCW is seen not as how human interact with computers but how they interact with each other through computers. This brings into considerations issues from sociology, psychology and computer science.

8 Information systems research and development

(Benbasat et al, 1987) Using research cases, this paper argues for the usefulness of using case studies in management information system (MIS) development projects. Using the insight from the study, the paper explains how these cases could have been performed better.

(Tait and Vessey, 1988) This paper analyzes many information systems projects to conclude that when involving users in complex systems, sufficient resources must be provided to prevent project failures in spite of user participation.

(Baronas and Louis, 1988) This paper argues that involving users in implementation, not in development, can improve information system acceptance.

(Weitzel and Andrews, 1988) This paper describes the practical issues involved in implementing a knowledge-based system by a joint project of a research institute and the company that expects to use the system. The paper includes recommendations for executing similar projects.

(Kaplan and Duchon, 1988) This paper describes the combination of qualitative and quantitative methods in research using one case study of MIS development project. The paper discusses the learning that researchers gained in the course of the project through such analysis methods.

(Lee, 1989) This paper argues that the case-study approach to doing MIS studies can be rigor as traditional methods.

(Barki and Hartwick, 1989) This paper argues that past research did not demonstrate that user involvement is beneficial. The reason is that user involvement should be assessed not based on whether users participated in the project but whether they were committed to the project, that is, by using the participants subjective psychological state rather than the simple observable behavior.

9 Practitioners perspective

(Lewin, 1946) A paper in a special issue on action and research, this paper is one of the first papers on action research. It argues against the move to basic research and discusses the alternative for studying two issues: general laws of group life and understanding of specific group life situations. The integration of many disciplines is required to support such studies.

(Blissett, 1972) This book examines the role of politics in science. The aim is not to denigrate science, but to demonstrate that it involves more than theories and experiments to include the generation and resolution of conflicts between the players of science.

(Fishlock, 1975) This book describes the relationships between science and technology and other concerns, such as economics, through an analysis of several major industries in Britain.

(DeMillo et al, 1979) This paper illustrates the social processes underlying the determination of mathematicians' confidence in the correctness of theorems. Since such social processes are nonexistent in program verification, there cannot be confidence in program correctness.

(Argyris, 1980) A management scientist perspective of social science. This book describes some of the contradictions in common views of social science and attempts to provide a foundation for action science.

• (Reason and Rowan, 1981; Reason, 1988) These edited volumes contain many perspectives of action research. The first book provides a broad introduction to action research including its philosophy, methodology, experience, and future directions. The second book elaborates on group research and the validity of action research but mainly concentrates on reporting on experiences from action research projects.

(Grinnell, 1982) A biomedical scientist perspective. This book describes the social aspects of doing science, such as attitude, process, and institution, drawing on experience from biomedical science.

(Schön, 1983) This book locates the sources of practical knowledge in the process of reflection-in-action drawing on observation of several practitioners in diverse fields. The book criticizes scientists for their lack of interest in practical competence.

(Ziman, 1984) This book attempts to integrate the insight that historians, philosophers, sociologists, and researchers have had on the practice of science. The book discusses many issues starting with details of doing research to communication, authority, and other social issues of research practice.

• (Schuster and Yeo, 1986) This edited volume contains historical studies on the rhetorical and political dimensions of a particular methodology. While these studies reject the existence of a single general scientific method, they affirm that the historical study of methods is important.

(Redner, 1987) This book discusses the relation between the development of science and the social organization of science. Science no longer resembles what it used to be before World War II; it has become less orderly, competitive, political, and more powerful. After discussing some pitfalls of science the book proposes a new way of organizing world science.

(Casti, 1989) A mathematician/system scientist perspective. This book reviews the major views of science progress in the philosophy of science. Subsequently, the book analyzes several significant questions of contemporary scientific thought. The question of the possibility of strong AI receives a positive answer.

(Addis, 1990) This book is an engineer's perspective of the relation between structural engineering and architecture theories and their practice. Progress in these fields over history is described as a sequence of revolutionary changes in the sense of Kuhn.

(Vincenti, 1990) An engineer perspective. This book demonstrates through case studies in aeronautics that in the process of design, engineers create new knowledge. Therefore, engineering is not really an applied science.

• (Palumbo and Calista, 1990) This edited volume discusses the relation between implementation research and the outcome of public policy. The inability of research to predict the outcome suggests that different ways of doing implementation research may be appropriate. The foundations of different worldviews are discussed in various chapters.

• (Guba, 1990) This edited volume in an excellent comprehensive source on the alternative worldviews (or paradigms) that govern research in the social sciences. The contribution from education researcher includes discussions on the issues that are critical to any inquiry.

(Efron and Tibshirani, 1991) This paper discusses statistical techniques that were made possible due to the availability of computers. These techniques allow for drawing valid statistical inferences without making various assumptions required to achieve tractability in traditional mathematical models of statistical analysis.

(Peters, 1991) This book provides a critique of ecology and environmental science which neglect the importance of predictive power while concentrating on rationalization and historical explanations. From such studies the quality of predictions is poor and inconsequential to practice.

• (Whyte, 1991) This edited volume presents Participatory Action Research (PAR) as a worldview that can advance both research and practice. The volume contains many example projects that demonstrate the ideas and a comparison with action research or action science.

• (Smith and Dainty, 1991) This edited volume discusses research methodology of management science. It contains contributions on the two diametrically competing perspectives: objective, positivist, "hard," which they term *from the inside* and subjective, ethnographic or "soft," which they term *from the outside*. An interesting part deals with different social issues pertaining to research including the doctoral dissertation context and politics in action research.

(Schumm, 1991) This book describes an earth scientist perspective on the approach to doing research. An approach and not method because there is no single method that earth scientists adopt. The book includes some of the pitfalls awaiting researchers in their practice.

• (Floyd et al, 1992) This book provides an excellent constructivist perspective of software programming practice. It bears high relation to AI inasmuch as programs are viewed as theories or as the basic experimental setup.

• (Gilliers, 1992) This book is an elaboration on two opposing perspectives of historians of mathematics on whether there were revolutions in the development of mathematics. The books contains examples of what can be interpreted as such revolutions.

10 Engineering design and manufacturing research

(Dixon, 1987) This paper argues that the scientific method must be exercised in design research for creating a scientific theory of design. A particular emphasis is placed on computable design theories.

(Antonsson, 1987) This paper argues that better hypotheses generation and testing is required to improve design research. A simple six-step process is briefly illustrated as an acceptable approach.

• (Göranzon and Josefson, 1988) This edited volume contains a wide range of topics related to the use of AI technology in practice as reflected by the research on expert systems in Britain and the work-life emphasis in Scandinavia.

(Amarel, 1989) This report argues that a science of design that leads to computer methods can improve design productivity. Such science could be advanced by developing and testing AI techniques for solving realistic complex problems. Several examples of such projects are presented and an agenda for future research is outlined.

• (Rosenbrock, 1989) This edited volume contains contribution discussing the application of AI technology to human-centered systems in manufacturing.

(Muster and Mistree, 1990) This paper discusses the implication on engineering design research caused by moving from a mechanistic conception of issues to a holistic systems thinking. The paper proposes a set of criteria for evaluating research proposals.

(Corbett et al, 1991) This book discusses methods for conducting collaborative interdisciplinary projects between engineers, sociologists, and users, for building human-centered manufacturing technology. The "borders" the book wishes to cross are those between engineering and social science, between theory and practice, and between cultures of different participants.

(Ullman, 1991) This paper provides a grim summary of the status of research on design theory in the U.S. The lack of philosophical foundation of research is stressed.

(Konda et al, 1992) After criticizing present approaches in design theory, this paper develops the concept of shared memory in design as a theme for understanding design. The paper proposes research programs that will allow designers to benefit from shared memory.

(Reich, 1992) This report attempts to delineate the gap between design research and practice from philosophical, theoretical, and practical perspectives. An approach to doing research based on participatory research is proposed to bring research and practice together.

(Reich, 1993a) This paper discusses the need to report the process of doing research in addition to research results; otherwise, wrong paths and fruitless avenues are likely to re-appear in other projects as well. The ideas are exemplified by the report on the development of the learning system Bridger.

(Reich, 1993b) This paper argues that there is not one scientific method that is appropriate for design research. Rather, many methods must be practiced, studied, and reflected upon. An elaborate sample of issues related to the proposal in (Antonsson, 1987) is presented.

(Fenves et al, 1994) This paper discusses the evolution of research on standard processing and attempts to explain the reasons for the lack of dissemination of research results into practice.

• (Rehak, 1994) This edited volume contains the views of researchers on various issues of computer-aided engineering (CAE) such as the relation of CAE to research and practice, CAE research on product models and integrated systems, research approaches, and future directions for CAE research.

(Dym and Levitt, 1994) This paper discusses the evolution of CAE research from its early promise to its present impasse. The paper attempts to explain some of the reasons for this situation and proposes a shift in education as one of the ways to improvement.

(Garcia et al, 1994) This paper describes a project for developing computational support for writing design documents. The project starts from an elaborate set of observational studies of practitioners, followed by conjecturing several hypotheses, designing a computational support and testing it with practitioners. Methodological issues in conducting such studies are also discussed.

(Lowe, 1994) This paper describes the philosophy and application of proof planning to configuration problems. Central to the methodology is the hypothetico-deductive approach of hypothesizing, validation through tests and hypotheses modifications.

(Steinberg, 1994) This paper discusses two methodological issues of doing research on AI and design: the application of AI methods to multiple tasks for proper testing and the collaboration of researchers with experts for developing meaningful research.

(Tomiyama, 1994) This paper discusses the evolution of ideas in General Design Theory and their incorporation into developing new technologies. The methodological issues in doing CAE research are exposed through the discussion.

(Reich, 1994a) This paper reviews the central issues in studying research methodology by dividing the study into three layers: worldviews, research heuristics, and specific issues.

(Reich, 1994b) This paper argues that the problems of CAE research are rooted in its deficient methodology which does not match the main objective of CAE research: improved practice.

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