Aline Dresch · Daniel Pacheco Lacerda
José Antônio Valle Antunes Jr.

Design Science Research

A Method for Science and Technology Advancement

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Foreword I

Design Science Research (DSR), also known as Constructive Research, is a methodological approach concerned with devising artifacts that serve human purposes. It is a form of scientific knowledge production that involves the development of innovative constructions, intended to solve problems faced in the real world, and simultaneously makes a kind of prescriptive scientific contribution. An important outcome of this type of research is an artifact that solves a domain problem, also known as solution concept, which must be assessed against criteria of value or utility.

The interest in this scientific research approach has emerged recently in different fields, such as information systems, business management, and management accounting, mostly due to the criticism that some of those academic communities have suffered for the lack of practical relevance of the scientific knowledge being produced. It occupies a middle ground between traditional scientific approaches, mostly descriptive, and context-related problem-solving knowledge produced in practical situations.

In fact, DSR has been pointed out as a suitable research approach when researchers need to work in close collaboration with organizations, for testing new ideas in a real context. Therefore, it can be used as a form of knowledge production for achieving two different purposes in research projects at the same time: producing scientific knowledge, and helping organizations to solve real problems.

The literature on DSR is still very scarce, and this book presents a comprehensive description of what this approach is about. It provides a historical perspective as well as introduces the main concepts involved in DSR, and compares it to descriptive research methods, normally used in the Natural Sciences or Social Sciences. Moreover, interesting discussions on the nature of the research process in DSR, and on the set of possible outcomes is also included in the book.

It is a great pleasure for me to introduce this book due to the fact that it is the results of the work of a team of people, Aline Dresch, Dr. Daniel Lacerda, and Dr. José A.V. Antunes Jr., who have attempted, through this research work, to make a contribution toward improving the quality of Engineering research, both in terms of rigor and relevance.

Interestingly, this book could be regarded as the main artifact produced by a research project that involved the three authors, being a useful resource for researchers interested in applying DSR. Although the book might call the attention of academics from several fields of research, it fills an important gap in the literature on research methods for engineering students. It is well founded in the literature, and some parts of the book present clarifying examples extracted from Industrial Engineering research projects.

Finally, it is necessary to recognize that this methodological approach is fairly new, and that further studies are necessary to understand and define it from the epistemological perspective. This can be partly achieved by discussing and reflecting on the outcomes of DSR projects. However, I am sure that this book makes an important contribution for this journey. For this reason, I strongly recommend it to be used in courses on research methods, especially for engineering and design students.

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Foreword II

This book provides a valuable further step in the development and dissemination of knowledge on Design Science (DS) and Design Science Research (DSR). Briefly, DS can be conceptualized as a body of valid knowledge on designs and designing, produced by rigorous research and DSR as research producing this type of knowledge. In disciplines like engineering and medicine DSR is mainstream research, in others not yet. Nowadays, in more and more other academic disciplines DSR is getting more and more an accepted place in the domain of their research. Nevertheless, there still are misunderstandings in the nature of DS, different from the explanatory knowledge of much mainstream research, and of the research strategies producing DS. Many academics still feel that the mission of *all* academic research is to understand the world as it is and are wary of research aiming to develop valid knowledge to improve the world, thus dealing with the world that can be.

Therefore, it is important that books like this one are published. It aims to give insight into the developments of DS and DSR after Herbert Simon published in 1969 his seminal *The Sciences of the Artificial* and is written for an audience of researchers and students—from undergraduate to graduate and Ph.D. students—in the various management disciplines. It can also be of value to researchers and students in engineering disciplines to the extent that they are not only interested in designing material systems like machines, mobile telephone networks, or bridges, but also in the social context in which they are built and used.

The book starts with a discussion of some aspects of academic management research, bemoaning—as I also do—the gap between research and practice, leading to the promise of DS and DSR to bridge this gap. It is followed by a general discussion of approaches, strategies, and methods of academic research in general. Chapters 3 and 4 deal with the core business of the book, DS and DSR, which includes a discussion on the historical evolution of the ideas on DS and DSR.

Consultancy aims to improve a specific situation through developing and applying specific interventions, but academic research aims to develop generic knowledge. So also DSR aims to develop generic knowledge. Therefore, a following chapter discusses classes of problems and classes of artifacts, the basis for developing generic knowledge. The authors proceed with developing a 12-step procedure for doing DSR.

A separate chapter discusses a method to do systematic literature reviews, on the one hand because a systematic literature review was one of the bases of the book, on the other hand because it is, together with research synthesis, an important component of DSR. In explanatory research one can give several explanations next to one another, but in acting to improve one has to make a definite choice of action. In evidence-based, or research-informed practice, one bases this choice on a synthesis of the results of a systematic review of the literature on the field problem at hand. The book concludes with a reflection on the developments since the publication of Simon's seminal book and on their own contribution to this.

I wish this book a large readership. Good for these readers, good for the dissemination of insights into DS and DSR, and through this good for academic management research and for its potential to inform practice.

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Acknowledgments

First, I thank the opportunity for writing this book. We sincerely hope that it contributes to the advancement and strengthening of scientific and technological researches. I would like to point out that many people were fundamental to the development and accomplishment of this book, but I would like to highlight some special thanks here. First, I would like to thank Prof. Ricardo Cassel (School of Engineering/UFRGS) for encouraging me to advance in the academic career. This important step in my career put me into contact with bright people, and with challenging activities (the development of this book among them). I also thank the many contributions of Prof. Adriano Proença (GPI/DEI/COPPE/UFRJ), Prof. Carlos Torres Formoso (NORIE/PPGEC/UFRGS), and Prof. Michel Thiollent (UNIGRANRIO/PPGA), which were very relevant to the consolidation of this research. I also thank the following colleagues from the Modeling for Learning Research Group (GMAP | UNISINOS); our daily discussions were essential for carrying out this book: Prof. Dieter Brackmann Goldmeyer, Prof. Douglas Rafael Veit, Prof. Luis Felipe Riehs Camargo, Profa. Maria Isabel Wolf Motta Morandi, and Prof. Secundino Luis Henrique Corcini Neto. Each one of them helped to implement this book in their own special way. In particular, I would like to thank Prof. Luis Henrique Rodrigues (General Coordinator of the GMAP | UNISINOS) for generously having me in the research group, for his words of friendship, laughters, and especially for all the learning. I also take this opportunity to thank Prof. Junico Antunes for his contributions, criticisms, and suggestions which guided the development of this book. Also, I thank him for being a great supporter of this cause. Last but not least, I would like to especially thank Prof. Daniel Pacheco Lacerda for proposing me the challenge of writing this book in 2011 and, above all, for making me believe that it would be possible. I am and will always be very grateful for the opportunity, for the trust, and for all the learning. Daniel, you are definitely an example to be followed. I'm also gratefully thankful to my family, to my Mom and to my Dad. Thank you for the unconditional support you have always given me. I even thank you for having encouraged me to read and write when I was still in my childhood (that was essential for this challenge to became pleasurable). Finally, I would like to thank my love, Natanael, for all the patience, good humor, and dedication to me. Thank you for helping me in becoming a better person!

Aline Dresch

At this moment, we should thank those who played an important role in the development of this work. I would like to thank Prof. Dr. Ricardo Cassel (School of Engineering/UFRGS) for calling our attention to this theme by initially disseminating an article related to Design Science (DS). I thank the colleagues from the Pro-Engineering Program, funded by CAPES, in the Operation Management Model in Innovative Organizations—MGOOI Project. This project had the participation of many graduate programs, namely: PPGEPS/UNISINOS, PEP/COPPE/UFRJ, PEP-PE/UFPE, AI/INPI, and Poli/USP. This project was led by Prof. Dr. Adriano Proença (GPI/DEI/COPPE/UFRJ), an enthusiast of the theme. His intellectual brilliance, his reflections, and contributions were central to the development of our research. I also thank Prof. Carlos Formoso (NORIE/PPGEC/UFRGS) for the important comments and articles related to DS. I thank the colleagues at COPPE/UFRJ, which was decisive institution in my education, André Ribeiro (UERJ), Édison Renato (UNIRIO), Guido Vaz (UFF), Prof. Domício Proença Jr. (COPPE/UFRJ), Priscilla Ferraz (Bio-Manguinhos), and my advisor Prof. Dr. Heitor Caulliraux (COPPE/UFRJ), my undying respect and admiration. Certainly, this book would have not become real if I was not in a stimulating environment. Therefore, I need to thank those who are the basis of this environment. I thank Prof. Dr. Ione Bentz (PPGD/UNISINOS) for believing and decisively contributing for the formation of the GMAP | UNISINOS (Modeling for Learning Research Group). Her vision about the research, science, and academic doings inspire me today and in the future. I thank all colleagues from GMAP | UNISINOS (we are almost at our fifth year, who knew?). In particular, I thank Prof. Luis Felipe Camargo, Prof. Maria Isabel Morandi, and Prof. Secundino Luis Henrique Corcini Neto. I am deeply thankful to Prof. Dr. Luis Henrique Rodrigues (General Coordinator of the GMAP | UNISINOS) for all the teachings and learnings. Yesterday, my advisor; today, a great companion and mainly a friend-brother. As you would say, "We are together!" I thank Prof. Junico Antunes for the steady partnership, the great discussions, and intellectual constructs that are so good to our Master and Ph.D. students of PPGEPS/UNISINOS (unfortunately, increasingly rare in the academia). I deeply thank Aline Dresch for believing and giving her best to the development of this research and work. Over these 4 years, you have acquired my admiration and appreciation. As the fans of the immortal (*Grêmio Porto Alegrense*) would say: *"O sentimento não se termina"* ("The feeling never ends"). Finally and most importantly, I thank my family Carina (Xuxu), Caio and soon, Serena Lacerda. Carina, you are the co-author of the major "works" of my life. These "works" originated from and were built with much love. Our children have taught us the real meaning of a word that is so vulgarized and in which I believe so much: love. Thank you for your companionship, support, and inspiration since the beginning, today, and ever, as I intend to. I love you more than you can understand! Finally, I will leave a popular wisdom of life in which I strongly believe: *"Só o amor constrói"* ("Only love builds"). This guides me both personally and professionally. Be assured that this book was developed with my best.

Daniel Pacheco Lacerda

Initially, I would like to recognize that the Design Science Research (DSR) theme came to my attention through a series of papers passed on by Prof. Ely Paiva. As Production Engineering lacks methods that can contribute to the development of prescriptive nature works, the reflections on the DSR method were essential to complement and advance in relation to the methods that we have often used, which are the Case Study and the Action Research. Undoubtedly, Prof. Ricardo Cassel was also essential as he sought to disseminate articles associated with the Design Science (DS) among PPGEPS/UNISINOS students and teachers.

Due to our historic partnership with GPI/COPPE, we immediately passed on the articles and initiated reflections on the DSR Method with our longtime partners, Profs. Adriano Proença and Heitor Mansur Caulliraux. In addition, we encouraged PPGEPS/UNISINOS students to address the issue with the maximum depth possible, being that the dissertations developed in the last few years were fundamental for making it possible to carry out this project.

Also, we immediately dealt with the subject in the "Operation Management Model in Innovative Organizations—MGOOI" Project, funded by CAPES, in the Pro-Engineering Program context. Several relevant discussions took place in the scope of this project, with the participation of the PPGEPS/UNISINOS, PEP/COPPE/UFRJ, PEP-PE/UFPE, AI/INPI, and Poli/USP institutions, in particular with Profs. Adriano Proença and Mário Sérgio Salerno, discussions which significantly pro-actively contributed to the preparation of this book.

Our contacts with Prof. Carlos Formoso, who is developing and coordinating several research works using the principles of the DS in the NORIE/PPGEC/UFRGS, were also relevant.

My objective insertion in the method theme was during my Ph.D. studies in Business Administration at UFRGS (1996/1999), particularly encouraged by Prof. Francisco Araújo Santos. Since late 90s, I have been lecturing the scientific method subject in Masters and Ph.D. programs in Management and Production Engineering: PPGEP/UFRGS, PPGEPS/UNISINOS, and PPGA/UNISINOS. In this context, I would like to highlight the partnership with Prof. Yeda Swirsky, with whom I have exchanged several conversations and ideas over the last 13 years on the method theme, which is really multifaceted, fascinating, and relevant. Moreover, it is worth highlighting the effective contribution of the UNISINOS environment, particularly the Business School/PPGA and PPGEPS, to the set of scientific and technological nature works recently developed.

I also appreciate the partnership with Prof. Daniel Lacerda, with whom I have had constant and systematic theoretical debates, and made relevant practical constructions in the PPGEPS/UNISINOS environment over recent years. Aline Dresch, a professional with a future in Production Engineering, we recognize the essential efforts that led to the design, consolidation, and operationalization of this book.

Finally, I thank my wife Verônica Verleine Horbe Antunes, my mother Maria da Graça Moraes Antunes, my father José Antônio Valle Antunes (*in memoriam*), and my son Juandres Horbe Antunes, who is now studying Production Engineering at UFPEL, for the unrestricted support to my academic activities developed over the past 30 years.

Junico Antunes (José Antônio Valle Antunes Junior)

Contents

Presentation

What does society expect from technology research?

This issue has always risen for this scribe during studies and research works in Production Engineering/Operations Management, along with the prospect of an upcoming research project or during the design of a research initiative; or when defining the theme, object and method in Master's Degree dissertations and Ph.D. Thesis. It is from this standpoint that this preface is written.

Through the voice of communities, organizations, businesses, leaders, managers, and students, what comes to us in the academia is the demand for designing, developing, planning, and implementing appropriate solutions. The issues raised involve whether such and which ways are indeed the most efficient, efficacious, and effective among the viable ones in situations 'a' or 'b'. The information and knowledge about the most advanced solutions and their degree of success in the existing implementations and their contexts, and the implication of this success on the progress of the technology in question as a whole; the possibility of developing a new solution to create, to push the technological frontier a bit further; all of this should be considered as alternatives, contemplated as a route, and works should always be informed to meet the final criteria of its performance in the real world, in different dimensions.

Maybe thousands of academic studies in Operations Management, taken here as an illustration of a technological area, have been conducted, in Brazil, as descriptions of real running solutions and analysis of the causality of results achieved by them, through case studies; or on what happened in a certain industrial sector through surveys relying on questionnaires and interviews. What happens/happened is studied, or the opinion/perception of large numbers is mapped. Analysis is developed to explain what was found and predict what would happen in such and which situations, according to this or that model, this or that "theory." The social sciences methods are emulated, the ambition of Nature sciences are mirrored. It is an agenda.

The "breakthrough" this book brings is to regain and affirm that this is not the only, and perhaps this is not "the" research agenda, for example, in Operations Management. This book starts from the recognition that there are Design Sciences.

A Design Science (DS) holds specific goals and ambitions; it seeks to establish artifacts of different natures for the solutions of problems (of "problem classes"—refer to Chap. 4 of this book).

Researching in a DS—in the terms of this book: to perform Design Science Research (DSR)—is unlike researching in the scope of a social or a natural science. Under the tentatively pragmatic understanding of this preface writer, DS is not "Applied Science[1]," for starters. Its purpose is not the mere translation in practice of the explanatory statements of the social or natural sciences, but yet the formulation and validation of design rules—conception, design, and implementation in defined circumstances—to be driven by the field professionals when they judge them relevant.

In addition, a DS recognizes, from its definition, that professionals in the field are not reduced to mere enforcers of the results of their findings—in other words, they are not mere appliers of stabilized technological rules. Given the multitude of situations they may encounter, and the complexity and dynamism of the real world, professionals as the ones of Operations Management trigger their "toolbox," or in accordance with what B. Koen defines what engineering is (refer to Chap. 5 of this book), trigger the "heuristics [that they know] to cause the best change possible in a poorly understood situation, with the resources available."[2]

Providing this professional in the field of reliable, tested, and validated technology rules (or technological propositions—refer to Chap. 4 of this book), of tangible or intangible artifacts whose behaviors are scientifically—that is, logical (expressed in theories, models or frameworks, for instance), and empirically—validated, is the direction of research in a DS. In this context, the research turns to achieve theoretical, experimental, and empirical results, which inform the act of designing. These will be added in the field to the insights derived from the social and natural sciences; to the current design practices of the profession; to the creativity of the professional (i.e., to what he/she invents); and to what he eventually only tacitly deduces from his/her practical experience.[3]

The DS in Operations Management will play a key role not only in the conception and designing processes, but also in questioning, testing, and validating cognitive or structured artifacts (design methods; organization and management solutions; operational policies; procedures, for example). In fact, they sometimes are presented to professionals and scholars under fanfares and exalted descriptions in publications of various kinds, as if they were universal panaceas—in not few cases in the so-called "airport literature," for example. It is for the DSR to unravel the actual scope of such claims, and if possible move into new proposals derived from their findings.

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1 Cf. Silva, E.R., & e Proença Jr., D. (2012) *Não ser não é não ter: Engenharia não é Ciência (nem mesmo ciência aplicada)*. Mimeo.

2 Koen, B.V. (2003) *Discussion of the method: conducting the engineer's approach to problem solving*. New York: Oxford University Press, *28*.

3 This list reflects the discussion undertaken by Vincenti, W.G. What engineers know and how they know it: analytical studies from aeronautical history. Baltimore: John Hopkins University Press, 1990, apud Silva, E.R. e Proença Jr., D. (op. cit.).

The DSR, for example, followed the hint offered by the real success of Toyota in Japan and in the U.S. at the end of the 70s to systematically describe the operation of the Toyota Production System (TPS) in books and articles; to then establish the circumstances and the contexts in which the policies and structures component of this system would satisfactorily work, making records of where its superiority in results was effectively verifiable; and then going deeper, grasping and describing the method by which Taiichi Ohno and Shigeo Shingo thought and responded to emerging challenges during the development of the TPS.[4] This last one if the best starting point for translating what has been learned from the TPS to the temporal/spatial reality faced by the designer/planner in charge of dealing with a real situation: its ill understood problem, to be solved under various constraints. Method, context, and circumstances of success, policies, and robust solutions: here is an example of a tested and validated artifact till where it is humanly possible. Always under the recognition that this artifact does not "automatically" bring the solution itself, but rather informs, as an available powerful heuristics, the process of creating a "new solution" in a given context, by definition strictly singular (spatially and temporally).

This book structures how a rigorous research is done within a DS, particularly in those that are identified with the broader field of Management, where this approach is not yet widely accepted. A solid bibliographic review allows identifying the convergence points presented in this literature, particularly in its most recent dimensions. It further seeks to (re)situate the methods of going to the field so that one can understand what is its best use in the DSR context. It is about discussing and reviewing how to develop a case study or survey when the objects and research objectives relate to cognitive and practiced artifacts, how to design them, the circumstances of its use and the expectable results (refer to Chap. 2 of this book).

To the judgment of this scribe, Brazil brutally lacks progress in this field. There are signs of massive resistance to the acceptance of such a perspective. An article on the subject, which was submitted for publication in a prestigious national academic journal, became, certainly in a large part by its own deficiencies, the target of strongly negative comments by the anonymous referees who refused it. However, among them there was a surprising identification of the whole issue of Management as a DS with a mere list of matters already resolved by product development techniques (!); and manifested perplexity and strong criticism to the importance given in the article to the contribution of Hebert Simon (Nobel Laureate in Economics and author of the seminal book on the Design Sciences.[5] To dimension what such criticism seemed to imply in terms of the referee ignorance on the subject, refer to Chaps. 1 and 2 of this book).

[4] For a pioneer presentation of this aspect, refer to Antunes Jr., J.A.V. *"O Mecanismo da Função Produção: análise dos Sistemas Produtivos do ponto de vista de uma rede de processos e operações*", in Produção, vol. 4, no. 1, Julho, 1994, pp. 33–46. A similar cognitive nature operation apparently took shape when the MIT team that established the "lean production" term later developed the idea of "lean thinking".

[5] Simon, H.A. (1969) *The Sciences of the Artificial. Cambridge*, MA: MIT Press.

This and other signals coming from the Brazilian Academy suggest that this book can fill an important gap, and contribute to enlarge the necessary debate on the policies and practices of research in technological development in the country, among others. In fact, at a time when at least apparently there is a national consensus being forged on the need to increase the productivity of the Brazilian economy, the incorporation of the remarkable recent advances in technology, be it in the information and communication technologies level or in the materials and biotechnology level, among many to consider, will need to be made in a smart, methodical, and discerning way, if intended to be efficient, efficacious, and effective.

There is no historical time available for us to fall behind in this path. The best conception, design, and implementation heuristics available should be incorporated, and then move forward to the frontiers of the state of the art when possible. To test, learn, incorporate, move forward. To develop our local Design Sciences and expand the boundaries of possibilities for Brazil's future with them. I think that what society is asking for research on technology is not less than fulfilling its historic role of concretely contributing to the development of the country. This book will help the academia in particular to participate effectively in this process.

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Chapter 1
General Aspects Related to Research in Management

If you are a scientist, or a manager, you are not interested in the description of the system. You are rather interested in the difficulty in controlling and predicting its behavior, especially when changes are introduced.

(Goldratt 2008, p. 41)

1.1 Introduction

Research in management should attempt to bring together two realities—theory and practice. Although they may seem distant from one another, both theory and practice seek to create knowledge that can be applied to improve existing systems or, rather, to help in the design and conception of new systems, products, or services.

However, much of the research conducted in academia is never applied or never becomes known to professionals in business organizations. Ford et al. (2003) report that scientists worry that their work may rarely be applied in practice. Professionals, in turn, are eager to receive information that may be useful in solving their day-to-day problems (Ford et al. 2003). Therefore, a *gap* exists between what is developed in academia (theory) and what is, in fact, applied in organizations (practice).

One of the reasons for this gap between theory and practice concerns the lack of relevance of these studies for professionals in organizations. Starkey and Madan (2001) understand relevance as the capacity of the knowledge developed in academia to produce a significant impact on worldly practice. Daft and Lewin (2008) understand that research, in addition to being relevant to professionals, should produce recognition from the academic community, which ensures the advancement of knowledge. However, for research to be scientifically respected and reliable, it should be concerned not only with relevance but also with rigor, which should be present from its conception to the presentation of its results (van Aken 2005; Hatchuel 2009).

Hatchuel (2009) stresses that rigor can be achieved by using research methods when conducting investigative work. The choice of research method, in turn, should be aligned with the nature of the problem one wishes to study. Starkey et al. (2009)

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argue that one of the challenges in research is to elaborate a procedure in which relevance represents one of the conditions of rigor.

Greater rigor in conducting research work, and especially rigor in methodology, helps to ensure the work's validity and, as a consequence, its recognition as a reliable and well-conducted study. However, some criticism has been presented regarding the methods used in conducting research work. Susman and Evered (1978) state that the research methods used to study organizations have become more sophisticated over time. However, even sophisticated methods do not guarantee that the knowledge generated by the research is in fact useful for a real-world professional to solve practical problems, for example.

One must note that research methods comprise a set of steps that are recognized by the academic community and are used by scientists in the building of scientific knowledge (Andery et al. 2004). Adequate application of a research method is one prerequisite to constructing reliable scientific knowledge.

Given all of the above, the availability of a diversified portfolio of research methods may contribute to the advancement of knowledge in a given field of study. This follows from the need for methods that are appropriate to different research problems. Broadening the portfolio of research methods and the adequate characterization and implementation of these procedures have become common concerns in fields such as management (Craighead and Meredith 2008; Slack et al. 2009; Taylor and Taylor 2009).

Another point to be stressed is that studies discussing research in the field of management take as a main reference the goals and practices of studies conducted under the paradigm of the natural and social sciences. In fact, Romme (2003) and van Aken (2004) claim that most publications in the field of management consider that the goal of science is to explore, describe, explain, and occasionally predict. Therefore, the main focus of studies in the field of management is the development of research work that serves to guide the building of theories that explore, describe, and explain how reality works, particularly organizational reality (Craighead and Meredith 2008; Taylor and Taylor 2009).

However, this traditional method of building knowledge that is commonly applied in the field of management has faced extensive criticism (Hambrick 2007; Romme 2003; van Aken and Romme 2009; van Aken 2004). Hambrick (2007) states that the excessive attention paid to descriptive theories hinders the development of studies in the field of management that may broaden the perspective of future works.

One therefore expects that research in the field of management might not only explore, describe, and explain a given phenomenon but also study the design and creation of artifacts. These artifacts, in turn, may be described as "artificial objects that may be characterized in terms of goals, functions, and adaptations (…) that are normally discussed, particularly when being conceived, both in imperative and descriptive terms" (Simon 1996, p. 05). The artifacts are descriptive with regards to communication, the detail ascribed to their main components, and the information about the artifact itself. The artifacts are also discussed in imperative terms in the sense of determining the normative issues that involve building and applying the artifact.

These artifacts are designed and created to effect some change in a system, solving problems and allowing for a better performance of the system as a whole. The results of studying artifacts have a prescriptive nature that are aimed at problem solving (van Aken et al. 2012). However, due to the influence of traditional sciences as well as engineering on the field of management, some investigations conducted in these fields are forcibly characterized as studies of an exploratory, descriptive, or explanatory nature.

This being the case, the need for a discussion about the epistemological foundation and an alternative research method that supports works of a prescriptive nature becomes evident. Studies that provide prescriptions are actually common in fields such as production engineering, architecture, administration, and so forth. However, such studies fall victim to a traditional methodological categorization that is not always adequate to the type of investigation taking place; i.e., even when the results obtained by a study are of a prescriptive nature, the authors use the traditional research methods (e.g., case study, action research, etc.) that are based on traditional science (the distinction between the types of science will be made later in this chapter and then in detail starting in Chap. 2). However, in essence, these research methods support exploratory, explanatory, or descriptive investigations.

Nevertheless, it is well-known that the proper use of a research method and its adequacy to the problem being studied are significant factors in attaining the necessary research rigor. International periodicals tend to value articles that display the rigorous use of research methods, especially when such methods are recognized in the traditional sciences (Daft and Lewin 1990; Saunders et al. 2012).

Moreover, Daft and Lewin (1990) advocate for the need to modernize the research methods used in the study of organizations and suggest using prescriptive methods that employ *Design* concepts. These new research methods should also consider the inclusion and integration of other disciplines in addition to those traditionally recognized for conducting such research (Daft and Lewin 1990; Gibbons et al. 1994).

The integration of several disciplines provides a broader view of the problem to be studied, thus producing an increased possibility to increase a study's relevance to professionals. It is within this context of integrating disciplines, rather than applying one single discipline in conducting a study, that the discussion proposed by Gibbons et al. (1994) appears.

Gibbons et al. (1994) state that there are two types of knowledge production: Mode 1 and Mode 2. Mode 1 knowledge production is purely academic and refers to one single discipline. Mode 2, however, is transdisciplinary, aimed at solving problems, and normally occurs in the context of application (Gibbons et al. 1994). This subject will be further described in the following chapters.

van Aken (2005) states that the application of Mode 2 knowledge might contribute to the increased relevance of research results. This increased relevance might in fact motivate professionals in organizations to use the studies' results to improve their processes or even solve their problems. This approach to Mode 2 knowledge production is strongly related to the goals of *Design Science* when one considers that it has the mission of developing knowledge that can be used by professionals to solve their day-to-day problems (van Aken 2005).

Platts (1993) stresses the need to increase the relevance of academic works that study organizations. His idea is founded on the fact that, although organizations may display the need to have their processes improved, academic studies, even using well-established methods, do not always manage to provide adequate contributions to this end (Platts 1993).

Romme (2003) claims that for studies aimed at organizations to become more relevant, they should include *Design Science* as a means to produce knowledge and to conduct studies in this area. Thus, it is possible to identify the need for studies that unite the concepts of *Design Science* to the problems that scientists have been trying to address. This union, in turn, would contribute to increasing the relevance of such studies.

However, to operationalize the concepts of *Design Science* and ensure that studies using these concepts are carried out with rigor, one must first study a research method that is adequate for this operationalization. This research method is called *Design Science Research* (March and Smith 1995; Cantamessa 2003; Hevner et al. 2004; Manson 2006; Järvinen 2007; Chakrabarti 2010).

In this case, the proposal of a research method such as *Design Science Research* that is adapted to problems in areas such as management would serve to maintain the rigor necessary for investigative research. Most importantly, it might contribute to increasing the relevance of the studies conducted by bridging the gap between what is developed in academia and what is applied in organizations.

It is the realization of this necessity that is the foundation of the present book, which seeks to discuss the possibility of using other concepts and methods in conducting research in the areas of management and engineering. One of the concepts described in this book is *Design Science*, which according to Bayazit (2004) deserves to be explored in greater depth in the field of management. Furthermore, this book seeks to provide greater understanding of the research method known as *Design Science Research* as a possible method for conducting prescriptive studies. To meet the goals of this book, the following themes will be examined in the text:

- Historical contextualization and exposition of the foundations of *Design Science*;
- Presentation of the concepts related to *Design Science Research* as a research method for prescriptive studies; and
- Proposal of a method for conducting research work founded on *Design Science*, considering the products generated in each of the steps and the issues related to research rigor and validity.

It should be stressed that, although the concepts of *Design Science* and *Design Science Research* are relatively new, they have mostly matured in the fields of Information Management and Technology (Tremblay et al. 2010; Lee and Hubona 2009; Peffers et al. 2007; March and Smith 1995), although one also finds works in the general field of management (Xu and Chen 2011; Pandza and Thorpe 2010; Denyer et al. 2008; Plsek et al. 2007; Romme and Damen 2007; Manson 2006; van Aken 2004; Romme 2003; Worren et al. 2002).

However, it was not possible to find a synthesis of these studies or concepts for the fields of management or engineering. Nor was it possible to find a systematization or consolidation of these concepts that was aimed at applying the concepts to investigations in management and engineering.

It must be noted that, in developing this book, the authors used a theoretical, conceptual, methodological approach based on a broad bibliographic review and a compilation of the concepts found in texts by several authors who have studied *Design Science/Design Science Research*. By means of a systematic literature review, it was possible to identify a series of articles that describe the concepts and application of *Design Science* and *Design Science Research* from several perspectives.

Reading and organizing these articles allowed for the identification of several categories, which contributed to a better understanding of the concepts within *Design Science* and *Design Science Research*. Moreover, the organization of these categories allowed the authors to identify articles that present studies comparing or criticizing *Design Science* and traditional science. These categories also allowed the identification of fields in which *Design Science Research* has been studied or applied. In closing, the categories thus defined are application, investigation methods, problematization, and theorization.

In addition to supporting the development of this book, these categories allow one to visualize how the literature on *Design Science* and *Design Science Research* is distributed; the categories allow one to identify the logic of the organization of texts in which this paradigm and this research method are described. The identified categories and subcategories are shown in Fig. 1.1.

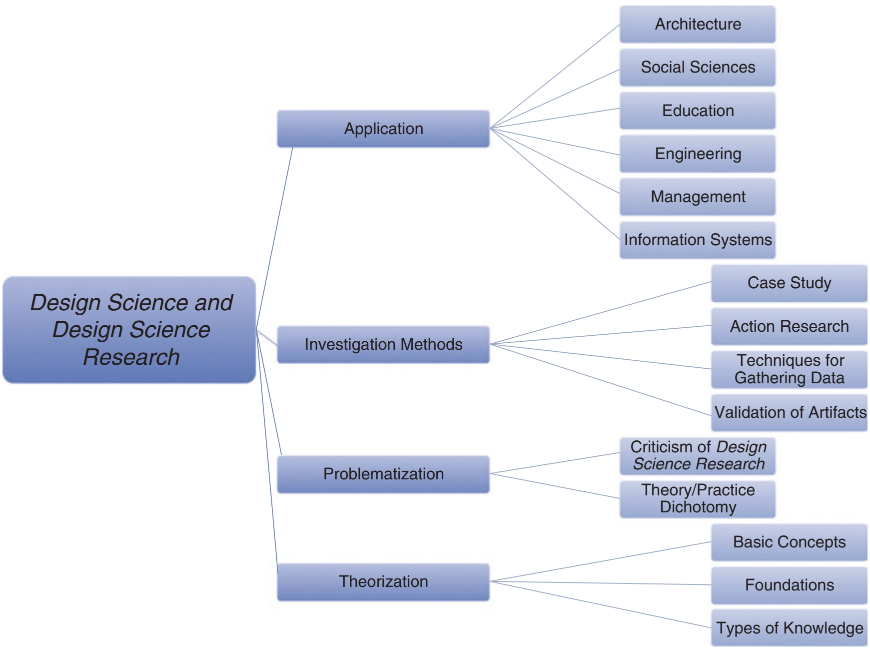

Fig. 1.1 Categories and subcategories for the analysis of articles. *Source* Elaborated by the authors

The "Application" category groups articles that demonstrate the practical application of *Design Science Research* concepts; it was divided into six subcategories according to the area in which the concepts have been applied. The subcategories of studies are Architecture, Social Sciences, Education, Engineering, Management, and Information Systems. As can be observed, the *Design Science* paradigm and *Design Science Research*, seen as a research method, have been applied to widely varied fields of knowledge. In this book, the emphasis will be on the application of this science and this method to the fields of management and engineering. However, the application of *Design Science* concepts and the method itself (*Design Science Research*) can be expanded to other fields of knowledge in which the goal is also to solve problems and construct artifacts.

The "Investigation Methods" category includes articles that in some way confront the concepts of *Design Science Research* and those of other research methods and related subjects. The subcategories defined for "Investigation Methods" are Case Study, Action Research, Data-Gathering Techniques, and Artifact Validation.

The "Problematization" category gathers articles that address Criticism of *Design Science Research* as well as those that debate the Theory/Practice Dichotomy faced by research authors. Therefore, its two subcategories are Criticism of *Design Science Research* and Theory/Practice Dichotomy.

The last category to be defined is "Theorization," which is split into three subcategories: Basic Concepts, Foundations, and Types of Knowledge. This category is of utmost importance in understanding the context of *Design Science* as well as understanding how the production of knowledge takes place when this approach is used.

Based on the categories defined and the classification of articles into each category, it was possible to identify how many reviewed articles were grouped in each category, as shown in Table 1.1.

Table 1.1 Categories and subcategories of the reviewed articles

Category	Subcategory	Number of articles
Application (use in practice) of *design science research*	Architecture	1
	Social sciences	1
	Education	15
	Engineering	1
	Management	2
	Information systems	1
Investigation methods and *design science research*	Case study	5
	Action research	8
	Data-gathering techniques	2
	Artifact validation	6
Problematization	Criticism of design science	7
	Theory/practice dichotomy	17
Theorization	Basic concepts	28
	Foundations	28
	Types of knowledge	4

Source Elaborated by the authors

Some of the values shown in Table 1.1 deserve special attention. For example, the authors ascertained that there were several articles in the field of Education, particularly when using the expression *Design Based Research* as a keyword. Another point worth noting is that in the category in which *Design Science Research* was related to other tools or methods for investigation (carrying out studies), it became evident that the method's relationship to Action Research stands out in comparison with the other research methods or techniques.

In the Problematization category, most of the articles provide discussions of the Theory/Practice Dichotomy, with many of the authors stating how much *Design Science Research* can bring these two realities together and reduce the *gap* that exists between them. Finally, in the category titled Theorization, most of the articles provide fundamental issues regarding *Design Science* and *Design Science Research*. Once the main topics related to *Design Science* were recognized through the review of these categorized articles, it became possible to structure the chapters in this book.

Yet another noteworthy point regarding the queries conducted on this database is the number of occurrences of articles referring to the theme at hand over the years. *Design Science* and *Design Science Research* have been perceivably gaining space in academia, although their numbers are still relatively small. Figure 1.2 shows the number of articles found and analyzed in each year of the chosen time horizon (1990–2013).

After a short overview of the approach in this book, it is befitting to note that it is divided into seven chapters in addition to this introductory chapter. Chapter 2—An Overflight Over Research—presents the concepts of traditional science as well as its differences from *Design Science.* It further presents the concepts and types

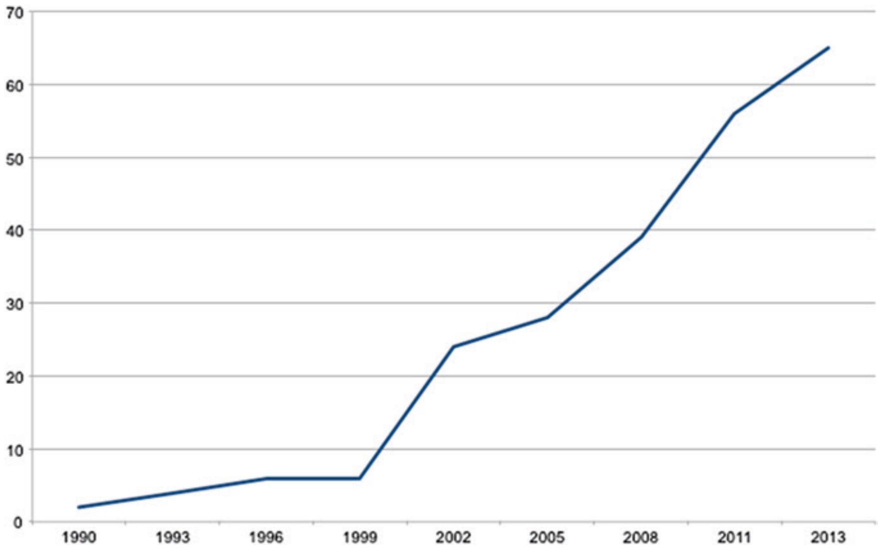

Fig. 1.2 Number of articles found in the chosen time horizon. *Source* Elaborated by the authors

of research that bear relation to the book's theme. Later, research methods and concepts that are commonly used by scientists in the fields of management and engineering are described, including the concept of work methods and the techniques used to gather and analyze data. Finally, considerations of the trajectory of science and the forms and types of knowledge production are provided.

Chapter 3—*Design Science*—The Science of the Artificial—describes the concepts related to *Design Science* and their history and contextualization. Furthermore, a theoretical comparison between *Design Science* and the traditional (i.e., natural and social) sciences is presented.

In Chap. 4—*Design Science Research*—the method's concepts are presented along with their foundations and criticism. A series of methods proposed for the operationalization of *Design Science* in several areas is also explicitly presented in this chapter. Furthermore, some aspects that scientists should pay special attention to so as to ensure validity, while conducting studies founded on *Design Science* are highlighted.

Chapter 5—Artifacts and Problem Class—presents thoughts on the importance of defining problem classes to conduct studies that are more relevant and to advance knowledge in general. The chapter also presents concepts and types of artifacts and the relationships between these and the Problem Class pertaining to the field of operations management.

Chapter 6—Proposal for Conducting Studies using *Design Science Research*—lists the main steps and makes recommendations for research authors who wish to use *Design Science Research* as the research method in their investigative work.

Chapter 7—Systematic Literature Review—presents the basic concepts and some methods that can be used to conduct a systematic review of literature. In addition, the chapter describes the importance of such a review in studies conducted using the *Design Science* paradigm.

In closing, Chap. 8—Future Perspectives—contains final thoughts regarding this book's theme.

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Chapter 2
An Overflight Over Research

> *Science has turned into the axis of contemporary culture. And, being the engine of technology, science ended up indirectly controlling the economy of developed countries. As a consequence, those who wish to obtain an adequate notion of modern society should study the mechanism of scientific production, as well as the structure and meaning of its products.*
>
> (Bunge 1980, p. 1)

This chapter presents the concepts of traditional science and Design Science. It further presents the concepts and types of research that relate to the theme of this book. Later, the types of research methods commonly used by authors in the field of management are presented, including the concept of the work method and the techniques used for gathering and analyzing data. In closing, considerations are provided regarding the trajectory of science and the forms and types of knowledge production.

According to Werneck (2006, p. 175), knowledge production can be understood as the "construction of universally accepted knowledge in a given historical time or as a process of learning of the subject". For knowledge production to be adequate, one critical factor for success is to guarantee that the right information is generated in the right format for the right user (Sun and Mushi 2010). Thiollent (1985) states that knowledge is produced based on the information obtained from two sources: (i) research authors, through their structuring of knowledge; and (ii) users who apply this knowledge in solving their real problems.

This chapter provides a short description of the traditional forms of producing knowledge. The focus is on the definition of science, particularly natural science, social science, and, briefly, artificial science, which is better approached later in the book. In addition, some concepts related to the research techniques and methods commonly used by researchers in the field of management are presented. Next, some topics are presented that are worthy of consideration regarding how knowledge that is termed "scientific" is produced.

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2.1 Science

To Ander-Egg (1976, p. 15), science is "a collection of rational knowledge, certain or probable, methodically obtained, systematized and verifiable, that makes reference to objects of one same nature". Science has no subjectivity; the knowledge generated from it is reliable because it can be proved (Chalmers 1999; Popper 1979).

Traditionally, the goal of science has been to develop knowledge about what exists by means of discoveries and analyses of existing objects (Simon 1996). One of science's functions is to help understand systems by uncovering the principles that determine their characteristics, their inner workings, and the results they produce (Romme 2003).

Science, in turn, can be classified into factual science and formal science. Factual science explores, describes, explains, and predicts phenomena. It is validated when it provides some empirical evidence. Conversely, formal science does not depend on empirical confrontation (Hegenberg 1969).

Formal science encompasses subjects such as logic and mathematics—subjects that are not approached in this work. Factual science is traditionally divided into natural and social sciences. Natural sciences encompass disciplines such as physics, chemistry, and biology. Social sciences include subjects such as sociology, politics, economics, anthropology, and history (Hegenberg 1969).

Natural sciences are those whose goal is to understand complex phenomena. The knowledge they generate is descriptive and analytical. Knowledge production occurs by means of a search for knowledge that is general and valid to the formulation of hypotheses (Romme 2003). "A natural science is a body of knowledge regarding a class of beings—objects or phenomena—of the world: it occupies itself with its characteristics and properties; with how they behave and interact" (Simon 1996, p. 01).

The main research activities involving the natural sciences are to discover how things are and to justify the reasons for them being so. Natural science research should be faithful to the observed facts while also being capable of predicting future observations to some degree (March and Smith 1995).

With the establishment of the main concepts of the natural sciences, some concepts regarding the social sciences can be presented. Social sciences seek to describe, understand, and reflect on human beings and their actions (Romme 2003). Knowledge arises from what people think about some given object. In studies using the approach of the social sciences, the researcher usually has a certain proximity to his or her object of study (people). However, research conducted in the social sciences is usually questioned based on its subjectivity because one usually cannot easily demonstrate how rigorously a study has been conducted (Romme 2003).

Thiollent (1985) claims that the social sciences in Brazil suffer from a dichotomy because studies are usually developed based on either a more scientific trend (whose approach is usually more quantitative) or a more humanistic trend (which considers people as key factors who should be considered as such in conducting studies).

Both research works supported by the social sciences and those founded on the natural sciences have as their mission the search for the truth, and their goals are to describe, explain, and predict to advance the knowledge in a given area (Denyer et al. 2008). It is worth noting that in general, authors in the field of management seek to find solutions to given problems or to design and create artifacts that are applicable to the daily routine of professionals. Therefore, a study that describes or explains a given situation is not always sufficient for the advancement of knowledge in this sense.

The preceding observations demonstrate the need for a science that broadens the comprehension of what has been undertaken in management, i.e., a science that has the ability to prescribe solutions to real problems as well (Denyer et al. 2008; Pandza and Thorpe 2010; Simon 1996). For this reason, Design Science covers areas such as medicine and engineering in addition to management (Denyer et al. 2008; Simon 1996).

The concept of Design Science was first introduced by Herbert Simon in his book entitled "The Sciences of the Artificial", published in 1969. In this work, Simon (1996) presents the differences between natural science and Design Science, translated here as Project Science or the Science of the Artificial. Table 2.1 presents a synthesis of the main characteristics of the natural sciences, the social sciences, and Design Science.

It is worth highlighting that research work must be developed for science to move forward and scientific knowledge to advance, whether to confirm some theory or to propose solutions to specific problems. Therefore, the following section presents the main concepts and types of research considered relevant for this book.

Table 2.1 Synthesis—natural sciences, social sciences, and design science

Characteristic	Natural sciences	Social sciences	Design sciences
Purpose	To understand complex phenomena. To discover how things are and to justify why they are this way	To describe, understand, and reflect on human beings and their actions	To design; to produce systems that do not yet exist; to modify existing situations to achieve better results. Focus is on solutions
Research goal	To explore, describe, explain, and predict	To explore, describe, explain, and predict	To prescribe. Research is oriented toward solving problems
Examples of areas that usually employ each of these scientific paradigms	Physics, chemistry, biology	Anthropology, economics, politics, sociology, history	Medicine, engineering, management

Source Elaborated by the authors based on Hegenberg (1969), Denyer et al. (2008), March and Smith (1995), Romme (2003), and Simon (1996)

2.2 Research: A Proposal for Its Structuring

A research work can be defined as a systematic investigation whose central goal is usually the development or refinement of theories and, in some cases, the solution to problems (Gough et al. 2012). One may further add that the need for research work arises from the realization that adequate and systematized information to answer some given problem is missing (Saunders et al. 2012).

The reasons that motivate one to conduct research may come from a theoretical gap or from some demand in the practice. Research of a more theoretical character is usually called basic or pure research, and its main goal is to ensure scientific progress, with no concern regarding the use in practice of the knowledge it generates (Saunders et al. 2012). This type of research is commonly found in academia.

Research of a practical nature is referred to as applied research, and its main interest is that the results generated by it can be used in practice, helping professionals to solve problems that occur in their daily work (Saunders et al. 2012). One must note, however, that although a distinction between basic and applied research exists, they are not mutually exclusive (Saunders et al. 2012). One may advance scientific knowledge while at the same time supporting professionals in solving their problems.

It must be noted that, to carry out research work, particularly scientific research, one must follow certain procedures to guarantee the reliability of the results. Usually, knowledge is developed by applying traditional approaches, such as those of the natural and social sciences. Figure 2.1 presents a structure that seeks to illustrate some points that must be taken into consideration when conducting research work for the aim of producing scientific knowledge. To illustrate the relationships and dependencies between each of the steps that should be taken into consideration when conducting scientific research, the representation used here is based on Newton's pendulum.

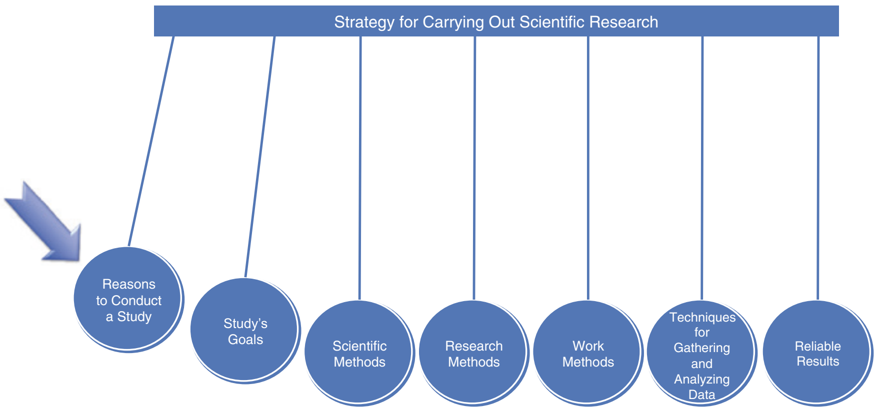


Fig. 2.1 Pendulum for conducting scientific research. *Source* Elaborated by the authors

Figure 2.1 seeks to unravel the structure that is traditionally used to produce scientific knowledge; this structure is based on the natural and social sciences. Next, to better understand what the pendulum is meant to represent, some of its concepts are described in detail.

The starting point in conducting scientific research is defining the reason for undertaking the investigation. This reason may be based on three main factors: (i) a new and interesting piece of information that the investigator wishes to share; (ii) an answer to some important issue; or (iii) an in-depth understanding of some phenomenon (Booth et al. 2008). Furthermore, the research process may be motivated by the following: (i) an observation of reality; or (ii) from the literature and previous knowledge by finding a gap that serves as a starting point for the study.

In addition to defining the starting point, the researcher must also define the goal he or she wishes to achieve with the investigation, i.e., whether one wishes to explore, describe, explain, or predict some behavior of the phenomenon being studied. To reach this goal, the researcher should select the scientific method that will guide his or her research work. The scientific method used will be directly influenced by the starting point of the study itself; i.e., whether the work starts with an observation of reality or by ascertaining a gap in the theory.

Once the research goal and the scientific approach that will guide the investigation have been defined, the researcher must now define the research method that is best suited for carrying out the study. Thus, researchers select the research method that is most adequate to their type of investigation. An adequate choice of research method aids the researcher in defining his or her own work method, which, in turn, ensures that the research work is carried out properly.

Elaboration of a work method is fundamental both to guide and support the researcher in carrying out his or her work and to guarantee that other researchers can use this method to replicate the study (Mentzer and Flint 1997). Note that, to elaborate a research method, one must choose and duly justify the techniques for gathering and analyzing the data to be used by the researcher.

One particularly noteworthy aspect is the need for the elements of the pendulum shown in Fig. 2.1 to be aligned. A lack of alignment between these elements may compromise or, more importantly, bias the results of the study. Another aspect of a misalignment is the difficulty of providing a systemic and systematic understanding of the adopted procedures and the way in which these procedures contribute to the study meeting its goals. Therefore, the researcher must know each element in the pendulum, select a strategy to address them, and justify his or her choices of methodology. An adequate stance and justification should serve as evidence of the care taken in carrying out the research work. Moreover, by means of this definition process, the research author can refine the methodological choices that provide support for the results of the research work being conducted.

In particular, one must explicitly present the procedures and their justifications in configuring the work method and the techniques for data gathering and analysis. However, to achieve this, some prior decisions are required with regards to both the configuration of the work method and the choice of techniques for gathering,

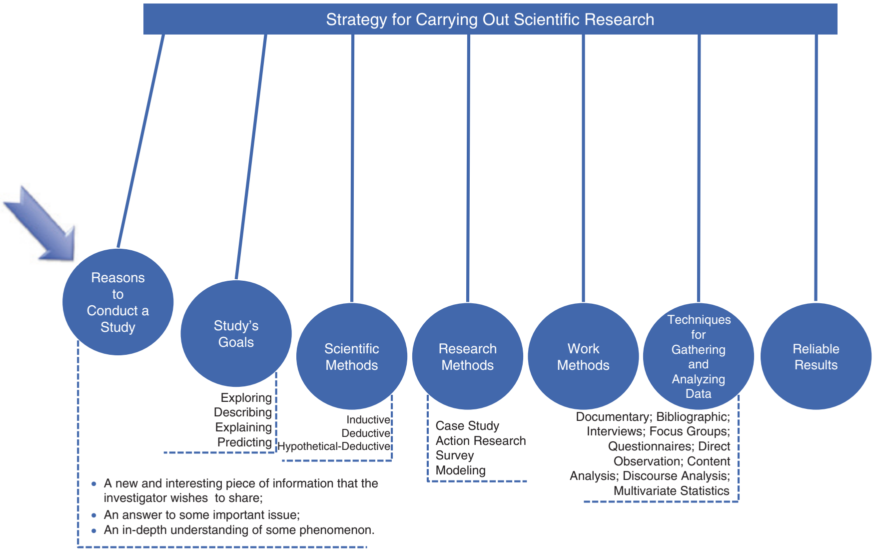


Fig. 2.2 Pendulum for carrying out scientific research. *Source* Elaborated by the authors

treating, and analyzing the data. Figure 2.2 synthesizes the main topics regarding the pendulum's elements that must be addressed.

In the following sections, the topics briefly highlighted in Fig. 2.1: Pendulum for conducting scientific research is presented in detail, and the limitations of using these approaches in carrying out research work in the field of management are shown. Note that the following sections do not aim to be exhaustive in regard to the scientific method, research method, work method, and so on; above all, the sections seek to address the main topics that are relevant to this book in particular.

2.3 Scientific Methods

This section presents the main scientific methods that guide the authors of studies in the field of management. The scientific method is a perspective on or premise about how knowledge is constructed. Therefore, a researcher must adopt a strategy and clearly state the scientific method that will serve as a guide in developing his or her research.

As one can observe in Fig. 2.3, researchers should take a stand regarding the scientific method that will guide the investigation shortly after defining the research goals. The researcher must also take into consideration his or her motivations to conduct the study. Later, the definition of the scientific method will guide the selection of the research method to be employed.

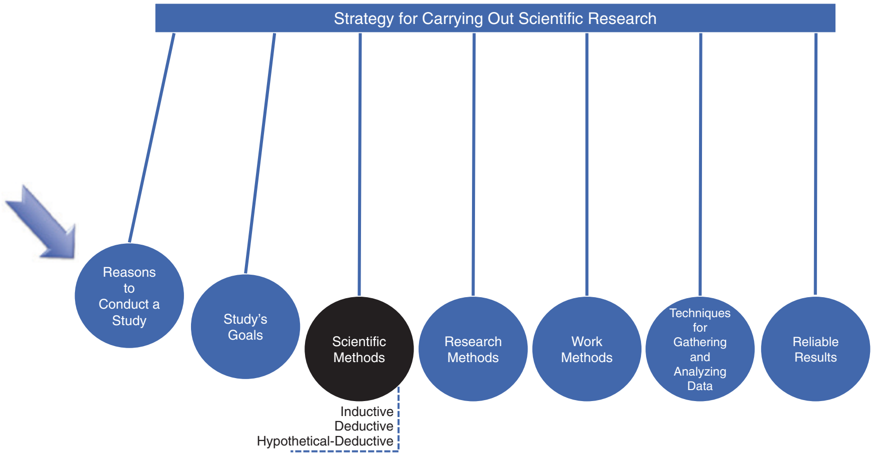


Fig. 2.3 Pendulum for conducting scientific research. Scientific methods *Source* Elaborated by the authors

2.3.1 Inductive Method

The inductive method is founded on premises and is stemming from the process of inferring an idea from previously ascertained or observed data (Saunders et al. 2012). According to Chalmers (1999), for an inductivist researcher, science is based on observation. Observation is the key point in constructing scientific knowledge. From the definition of propositions based on the scientist's observations, it is possible to generalize knowledge and propose a universal law; i.e., using particular and duly observed data, the scientist makes an inference regarding that which is being studied (Camerer 1985; Saunders et al. 2012).

The scientist using the inductive method starts from the assumption that one can construct scientific knowledge by repeatedly observing a given object of study; i.e., based on these observations, one can propose theoretical foundations for the object of study (Chalmers 1999).

Therefore, from the inductivist's perspective, experience is fundamental in providing the foundations for knowledge. However, the observations should not suffer any interference from the researcher's personal opinions; the researcher should be as impartial as possible (Chalmers 1999). There are three basic steps in research work based on the inductive method. These steps are presented in Fig. 2.4.

However, extensive criticism has been made of the inductive method. One such criticism is the so-called "inductive leap", i.e., the route from "some" phenomena that have been observed to "all" phenomena, even those that have not been observed or those that cannot possibly be observed (Chalmers 1999; Eisenhardt 1989; Saunders et al. 2012).

The inductive method is commonly applied to research in management because studies in this area often spring from observations of reality. By observing facts,

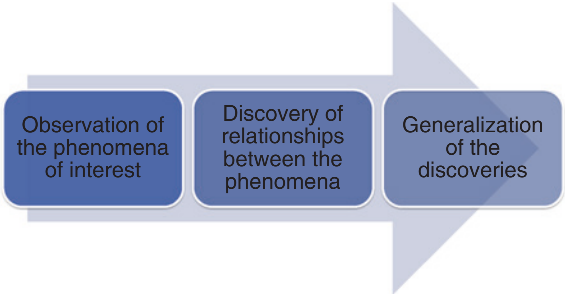


Fig. 2.4 Steps comprising the inductive method. *Source* Elaborated by the authors, based on Chalmers (1999) and Saunders et al. (2012)

the researcher starts building conjectures that can contribute both to the solution to a practical problem and to supporting new theories. In the following, some concepts related to the deductive method are presented.

2.3.2 Deductive Method

In the deductive method, the scientist starts from laws and theories to propose elements that may serve to explain or predict some given phenomena (Chalmers 1999). Chalmers (1999, p. 37) further claims that, in the deductive method, the "valid logical arguments are characterized by the fact that, if the argument's premise is true, then the conclusion should be true".

By using deduction, a scientist, knowing universal theories and laws, can build new knowledge based on this prior knowledge to explain and predict the behavior of the object of study. Figure 2.5 shows the process of knowledge production according to the approaches of induction and deduction.

The deductive method is characterized by the use of logic in constructing knowledge (Chalmers 1999). One significant difference between the inductive and deductive methods is that to develop the inductive method, one must necessarily start from the observation of phenomena, i.e., one must have an empirical basis. The deductive method starts from the proposition of laws and theories that encompass some given phenomenon, and knowledge is built from the definition of the premises and the analysis of the relationships between them.

One example of the application of the deductive method to studies in the field of management is the construction of conceptual models. The researcher starts from

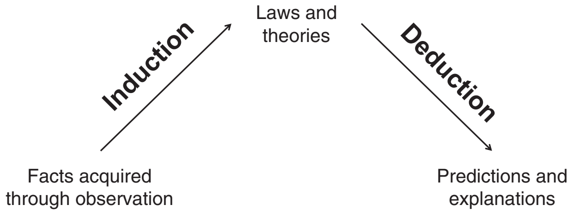


Fig. 2.5 Production of knowledge according to the inductive and deductive approaches. *Source* Chalmers (1999, p. 29)

previous theoretical knowledge and, in a logical manner, proposes some possible relationships among the variables. Later, he or she seeks concrete data to confront the model with reality. Based on the results obtained, the researcher can explain or even predict some behaviors of the system being studied. In the following section, some concepts related to the hypothetical-deductive method are presented.

2.3.3 Hypothetical-Deductive Method

Popper (1979) is one of the main authors who question the inductive method, claiming that it cannot be recognized as an effective scientific method. He presents the hypothetical-deductive method as an attempt to develop a scientific method that is adequate for the search for truth. This method is characterized by identifying a problem based on previous knowledge and proposing and testing hypotheses that result in predictions and explanations (Shareef 2007).

Hypothetical-deductive logic is used by falsificationist scientists, who believe that there is more value in refuting an idea or theory than in confirming it (Chalmers 1999). To these scientists, it is when an idea is refuted that the evolution and advancement of science takes place. According to Chalmers (1999), even if one cannot confirm whether a theory is true, one can still say that it is the best available at the moment.

Popper (1979, p. 184) states that "whenever we start explaining a conjectural theory or law by means of a new conjectural theory of greater degree of universality, we discover more about the world (…). And whenever we manage to render one such theory false, we make an important discovery". This statement reflects the defense of falsificationism, through which one seeks to refute a hypothesis in the search for advancement of scientific knowledge.

The falsificationist believes that science is a collection of hypotheses that can be proposed and tested to describe or explain some given behavior of the object of study. Furthermore, to be recognized as scientific, a hypothesis must be falsifiable (Chalmers 1999). Put in simple terms, one can say that the hypothetical-deductive method consists of the four steps presented in Fig. 2.6.

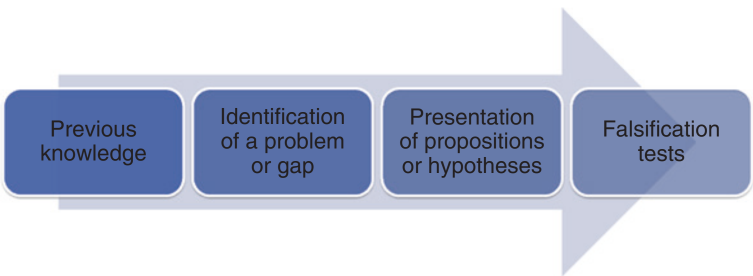


Fig. 2.6 Steps comprising the hypothetical-deductive method. *Source* Elaborated by the authors based on Chalmers (1999) and Shareef (2007)

In the hypothetical-deductive method, Popper (1979) suggests that a researcher should start from some previously constructed knowledge or some observed gap, propose new theories in the form of hypotheses or propositions, and put them to the test. Once tested, if these hypotheses are confirmed to be true, then they have been corroborated by previous experience. If the hypotheses yield a negative result, i.e., they are proved false in the tests, then they are refuted.

The hypothetical-deductive method can be found in works on management, for example, when the problem under investigation is related to assessing the quality of products and services. The researcher makes hypotheses and puts them to the test to verify whether the hypotheses are falsifiable or can be corroborated.

Finally, one could say that the scientific method or approach to be employed in an investigation should be chosen by in essence taking two factors into consideration. The first factor concerns the starting point that gave rise to the study, for example, whether the study originated in a theory gap, in a problem in practice, or directly from the observation of some phenomenon. The second factor that concerns the definition of the scientific method is the research goal, i.e., whether one wishes to explain, describe, explore, or predict.

These factors that address the choice of scientific method also concern the choice of research method to be employed. In view of the need to better understand the research methods that are commonly used in studies in the field of management, these research methods are described in detail in the following section.

2.4 Research Methods

This section addresses some of the foremost research methods used in studies related to management. Figure 2.7 illustrates how the chosen research method relates to other issues that should be taken into account by the researcher in defining his research strategy.

The importance of defining and justifying the research method is signified most of all by the fact that it helps the researcher ensure that his or her investigation will in fact provide an answer to the research problem. Furthermore, the adequate use of a research method also supports recognition of the investigation by the scientific community, providing evidence that the research work is reliable and valid for the field. Among the many existing methods, four have been selected as the most noteworthy; these methods are described next.

2.4.1 Case Study

According to Yin (2013), a case study is an investigation that is deemed empirical and that seeks a better understanding of a contemporary and usually complex phenomenon in its real context. Case studies are considered valuable because they

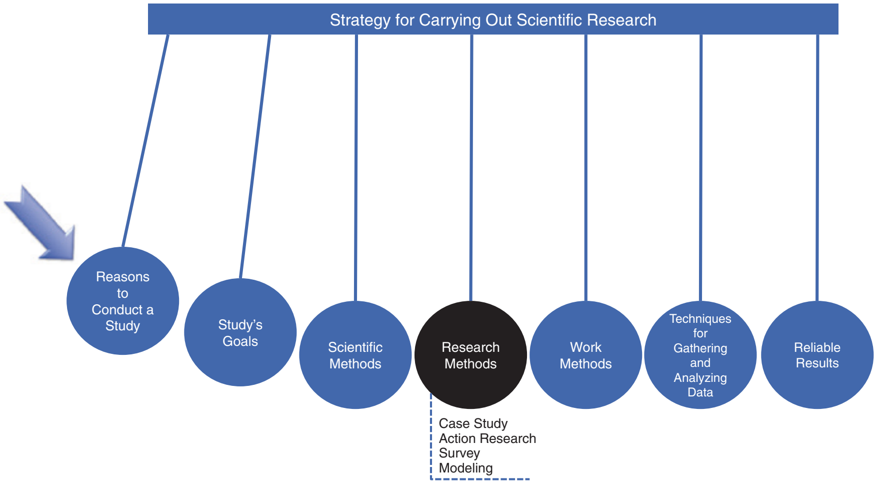


Fig. 2.7 Pendulum for the conduct of scientific research— research methods *Source* Elaborated by the authors

allow detailed descriptions of phenomena. They are normally based on a diverse set of data sources (Yin 2013).

The case study is particularly appropriate for the investigation of complex problems within the context in which they occur (Dubé and Paré 2003). Case studies ensure that the investigation and the understanding of the problem will both be in-depth (Dubé and Paré 2003).

It is characteristic of case studies to consist of a combination of data-gathering methods such as interviews, questionnaires, observations, and so on. This gathered evidence, which serves as a subsidy for the researcher, may be quantitative or qualitative (Eisenhardt 1989).

The foundation of case studies is the comparison of the collected data in which the researcher seeks to identify theoretical categories that can be used as a basis to propose of new theories (Eisenhardt 1989). Thus, according to Eisenhardt (1989), the main goals of a case study are (i) to describe a phenomenon; (ii) to test a theory; and (iii) to create a new theory.

In considering the general characteristics of case studies and their goals, one realizes their inductive nature. One of the reasons for this association is a study's starting point because a case study begins with the observation and analysis of real phenomena. Another reason for this association is that the scientific method assumes that theories will be generated, also one of the goals of case studies.

To meet the goals proposed by a case study, certain activities should be performed. The most important of these activities are listed in Fig. 2.8.

Note that case studies are essentially empirical and that the researcher acts as an observer and should not interfere in the study. Thus, to conduct a case study, the investigator must have great skill. In addition to not directly interfering in the

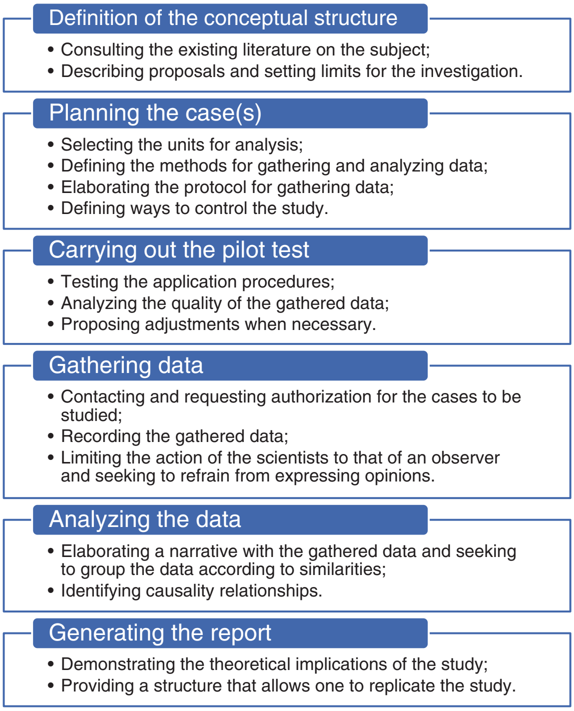


Fig. 2.8 Activities in a case study *Source* Elaborated by the authors based on Cauchick Miguel (2007, p. 221)

study, the researcher should carefully analyze the gathered data to verify possible behavioral patterns and to properly explain the phenomena (Ellram 1996).

Case studies are often questioned by the academic community in terms of rigor, and therefore, it is fundamental that the procedures used when carrying out case studies be made explicit, which grants additional credibility to the studies. Only with explicit procedures can readers of the study judge the solidity and adequacy of the applied methodology (Ellram 1996). Moreover, case studies tend to be exploratory, descriptive, and explanatory, which is typical of the natural and social sciences.

2.4.2 Action Research

The goals of action research are to solve or explain the problems that are found in a given system. It seeks to produce knowledge both for practice and theory. Similar to the case study, action research is exploratory, descriptive, and explanatory.

However, in contrast to the case study, the researcher in action research ceases being strictly an observer and takes an active role in the investigation. When this method is used, it is assumed that there is cooperation and involvement between the researcher and the members of the system being analyzed (Morandi et al. 2013). The researcher contributes to and interacts with the object of study (Benbasat et al. 1987; Thiollent 2009). The researcher has two roles when this research method is used: (i) he may be a participant in the implementation of a system; and, (ii) at the same time, he may wish to evaluate an intervention technique (Benbasat et al. 1987).

For a study to be classified as action research, there must in fact be an action by the members of the system being studied (Thiollent 2009). Furthermore, this action must not be trivial: it should be perceived as important to the studied context, thus justifying the reasons for the investigation (Thiollent 2009). The cycle for conducting action research, as well as its main activities, are presented in Fig. 2.9.

There are two aspects of the cycle proposed by Coughlan and Coughlan (2002) that are worth further elaboration. First, it is fundamental that the researcher understands the context in which the study will take place as well as the results that are expected at the end of it. Coughlan and Coughlan (2002) identify this element of understanding the context and goals as a prestage of the action research cycle but also one that is necessary for the study to develop well.

The second aspect to be noted is the monitoring stage. To Coughlan and Coughlan (2002), monitoring should be considered as a meta-stage because it should occur throughout the whole cycle established for conducting the action research.

Action research is fundamentally empirical and requires a qualitative approach. Moreover, at the study's conclusion, its results should be checked against the existing theoretical basis. Additionally, the implementation of the proposed solutions is mandatory to evaluate the results.

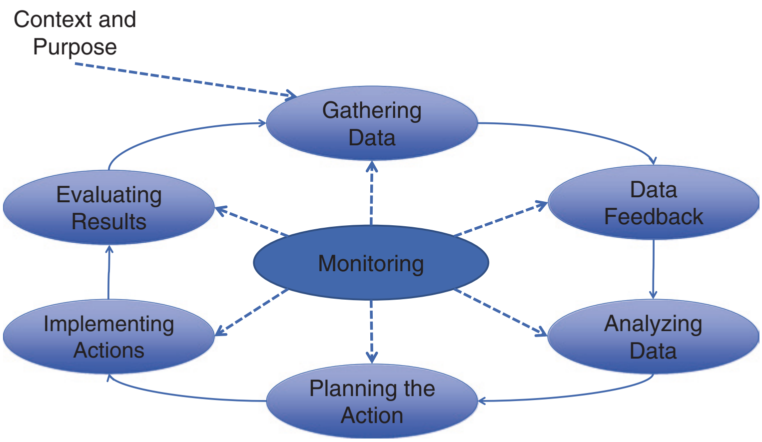


Fig. 2.9 Cycle for conducting action research. *Source* Coughlan and Coughlan (2002)

2.4.3 Survey

A study conducted using a survey approach aims to develop knowledge in a specific field. The investigation is conducted by means of gathering data and/or information to assess the behavior of people and/or the environment in which they act (Cauchick Miguel et al. 2012). Based on data gathering and analysis, the researcher can draw conclusions regarding the phenomenon or the population being studied.

A survey, similar to a case study or an action research, aims to explore, describe, and explain. However, depending on its goals, a survey may display some particular traits. Therefore, surveys are classified into three different groups: exploratory surveys, descriptive surveys, and explanatory surveys (Cauchick Miguel et al. 2012; Forza 2002). Table 2.2 presents the main characteristics of each type of survey.

Table 2.2 Characteristics of each type of survey

Element	Type of survey		
	Exploratory	Descriptive	Explanatory
Unit(s) of analysis	Clearly defined	Clearly defined and appropriate to the investigation's questions and hypotheses	Clearly defined and appropriate to the investigation's hypotheses
Respondents	Representative of the unit of analysis	Representative of the unit of analysis	Representative of the unit of analysis
Research hypotheses	Not necessary	Clearly defined questions	Clearly established hypotheses associated with the theory
Sample selection criteria	By approximation	Explicit, with logical argument; choice based on alternatives	Explicit, with logical argument; choice based on alternatives
Representativeness of sample	Not necessary	Systematic and with a well-defined purpose; random selection	Systematic and with a well-defined purpose; random selection
Sample size	Sufficient to include part of the phenomenon of interest	Sufficient to represent the population of interest and perform statistical tests	Sufficient to represent the population of interest and perform statistical tests
Questionnaire pre-test	Conducted with part of the sample	Conducted with a considerable part of the sample	Conducted with a considerable part of the sample
Return rate	No minimum	More than 50 % of the population under investigation	More than 50 % of the population under investigation
Use of other methods for gathering data	Multiple methods	Not necessary	Multiple methods

Source Forza (2002, p. 188)

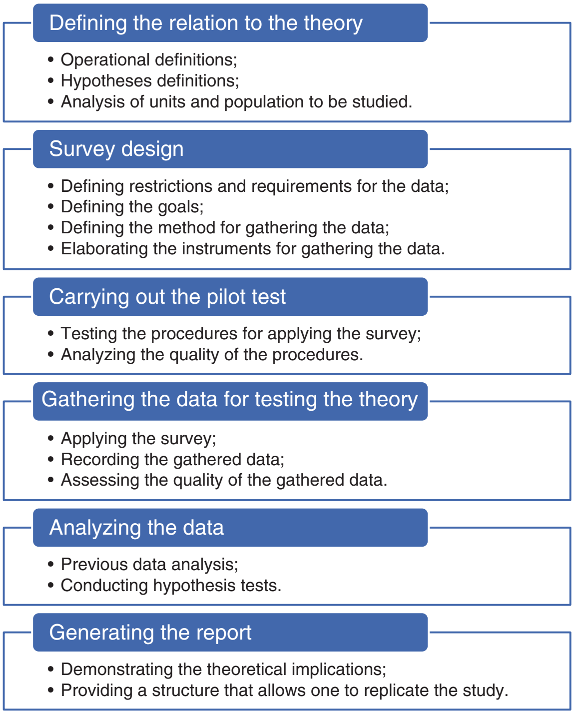


Fig. 2.10 Activities in a survey for theory testing. *Source* Elaborated by the authors based on Forza (2002)

However, independent of the research goal and the type of survey to be conducted, certain steps must be followed. These steps most of all seek to ensure that the research is rigorous. Based on Cauchick Miguel et al. (2012), these steps are described in Fig. 2.10.

Note that a survey, in contrast to a case study or action research, uses a quantitative approach. Moreover, one of the goals of studies conducted through surveys is to generate reliable data that allow for a robust statistical analysis.

Cauchick Miguel et al. (2012) claim that surveys may provide significant contributions to studies in the field of operations management. This contribution seems even more interesting when the study's goal is to develop a descriptive perspective of a given phenomenon or when one wishes to test existing theories (Cauchick Miguel et al. 2012).

2.4.4 Modeling

Modeling is a research method that supports investigators in better understanding problems. Models are simplified representations of reality that allow researchers to better comprehend the environment being studied (Neto and Pureza 2012; Pidd 1998). In the field of management, modeling is most commonly applied to operational research.

Table 2.3 Hard versus soft approaches

Characteristics	Hard approaches	Soft approaches
Problem definition	Seen as direct, unitary	Seen as problematic, pluralistic
Organization	Tacitly admitted	Requires negotiation
Model	A representation of the real world	A way to generate debate and insight about the real world
Result	A product or recommendation	Progress through learning

Source Pidd (1998, p. 115)

The concept of modeling is quite broad, and it is often used in an all-encompassing manner in studies in the field of management. According to Pidd (1998), modeling can be separated into two approaches: hard and soft. One should note that these two approaches are not mutually exclusive and may in fact be complementary to one another (Rodrigues 2006). Table 2.3 presents some of the differences that can be observed between these approaches.

In Table 2.3, one can observe that the hard approach to modeling is primarily based on mathematical grounds (Pidd 1998). This approach is best used when the problem to be studied is well structured and understood (Pidd 1998).

The soft approach to modeling considers the entire context of a problem. For this reason, the soft approach is most often used when there is a need to consider behavioral and contextual issues (Pidd 1998). Both the hard and soft approaches present several techniques for their implementation.

Some techniques of the hard approach, which can also be applied to research in the field of management, include linear programming, computational simulation, heuristics, and queue theory, among others (Rodrigues 2006). It should be noted that these techniques related to the hard approach are usually used when the researcher is seeking to optimize systems (Pidd 1998).

Among the hard modeling techniques, computational simulation stands out. Computational simulation is especially important for the study of situations in which considerably complex transformations take place frequently (Pidd 1998). The simulation technique is especially relevant when one seeks to explore or experiment with a given situation.

The use of computational simulation is interesting because it allows the investigator to find answers at a relatively low cost and very safely and swiftly, in comparison with experiments in a real context (Pidd 1998). Moreover, the usage of computational simulation as a modeling technique becomes especially interesting when the problems being studied are dynamic, interactive, and complicated (Pidd 1998).

The soft approach, in turn, also includes certain techniques that are directly associated with it, including, for example, the Soft System Methodology (SSM), which was first proposed by Checkland (1981) to address complex situations in which the hard approach proved insufficient (Pidd 1998). One characteristic of the SSM as an approach to modeling is that it emphasizes the learning process generated during its application (Pidd 1998).

Furthermore, the SSM allows one to create models of complex situations (Pidd 1998). These models can serve as a reference both in understanding and supporting the solutions to problems. One should note that use of the SSM is strongly related to the concept of Systemic Thought (Andrade et al. 2006).

Systemic Thought, in turn, is the basis for the construction of the Systemic Method, whose purpose is to support the solutions to complex problems and to generate learning regarding the problems and the situations in which they occur (Andrade et al. 2006). Systemic Thought can be perceived as an approach to be used when one wishes to see the whole because it allows the interrelations between the parts of a system to be analyzed instead of only analyzing events (Senge 1990). These characteristics of Systemic Thought certainly contribute to the modeling of complex problems targeted by researchers.

Having presented the foremost research methods used by authors of studies in the field of management, the next section presents some of the concepts and premises that guide the definition of the work method. The work method provides the organization of the activities that the researcher will conduct, and it also details and defines the techniques that will be used in carrying out each activity.

2.5 Work Method

The work method defines the sequence of logical steps that the researcher will follow to reach the goals he or she set for the study. It is essential that the work method is very well structured and that it is properly followed to ensure a study's later replicability (Mentzer and Flint 1997). A properly defined work method also provides greater clarity and transparency in the research process, which helps its validity to be recognized by other researchers.

In the work method, the researcher should describe the chosen research method by using the defined scientific method as a foundation. Moreover, to construct the work method, the researcher should define the techniques that will be used to gather and analyze the data that will be used to execute the study. In addition, this definition of the techniques to be used will support the researcher when defining the procedures to be used in triangulation. In addition to explicitly selecting the techniques for gathering and analyzing the data, the investigator must provide the reasons that motivated these choices. In fact, all of the decisions made by the researcher in the course of the study must be duly justified. The relationships between these many choices faced by the researcher are visualized in Fig. 2.11.

Research methods are generic methodological guidelines. The choice of a research method depends on a previous stand taken by the researcher regarding the scientific method. However, research methods must have a degree of generality to be accepted as valid procedures by the scientific community. The researcher must adapt and contextualize the research method to the specific investigation to be conducted.

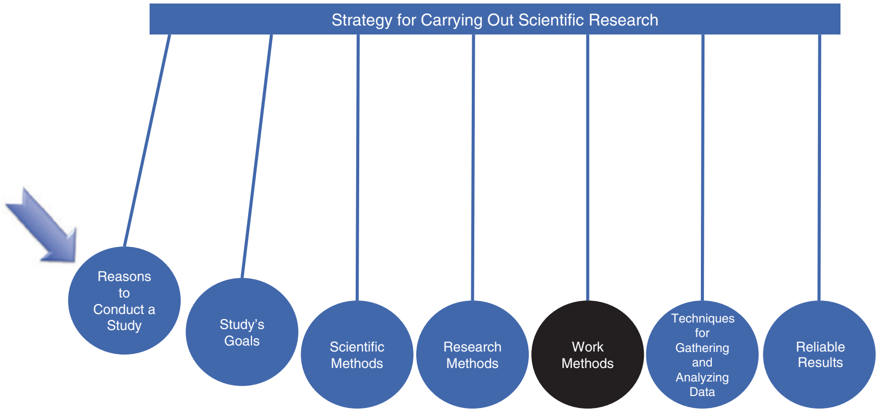


Fig. 2.11 Pendulum for conducting scientific research—work method. *Source* Elaborated by the authors

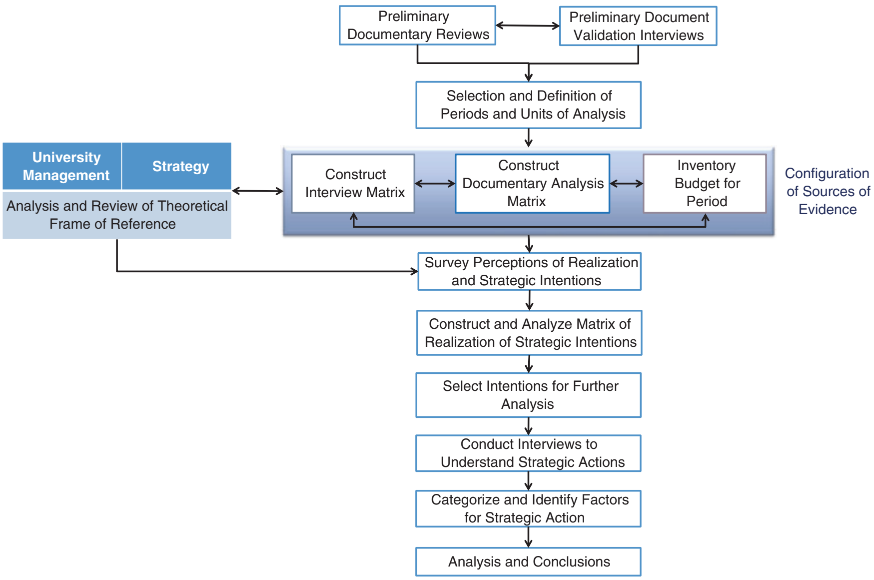


Fig. 2.12 Example of work method. *Source* Lacerda et al. (2014, p. 64)

Therefore, the work method will reveal the chosen research method. In a case where a study articulates several research methods, they are described through the work method. Specifically, the work method should present, in detail, the activities (steps) to be taken throughout the entire research enterprise. In addition to presenting these steps, the researcher must reveal and justify his or her reason for performing these activities and, most importantly, describe how these activities contribute to the researcher's conclusions, thereby increasing their reliability.

In the work method, the techniques for gathering and analyzing the data should be defined. For example, if the researcher intends to use more than one technique for gathering data, he or she must explicitly describe whether such techniques will be used in sequence or in parallel. The researcher must describe the analysis techniques used in connection with each data-gathering technique, i.e., that the work method provides and justifies the procedures for triangulation (of theories, methods, techniques, and data) (Mangan et al. 2004). By means of an illustration, Fig. 2.12 presents a work method that is revealed from a case study research method.

Based on the understanding of the concept of the work method, we now examine some research techniques that support researchers in undertaking their investigations. These research techniques are presented in the next section and are split into two parts. The first refers to techniques for gathering data, whereas the second part refers to techniques for analyzing data.

2.6 Techniques for Gathering and Analyzing Data

Techniques for gathering and analyzing data are fundamental to ensure the operationalization of the research methods and the work method defined by the researcher. Before selecting a technique to be used in conducting an investigation, a researcher must carefully consider the data being sought, including how it can be found, when it can be found, and who can actually find it.

In addition, the choice of techniques for gathering and analyzing data should be properly justified by the researcher. To justify this choice, the researcher must keep in mind that (i) the definition of how the data analysis will be conducted may determine the limits of data gathering and even the dissemination of the results and that (ii) the data analysis and interpretation are significant contributions of his or her research work (Amaratunga et al. 2002).

Furthermore, it is fundamental that the researcher, in defining the techniques for gathering and analyzing the data to be used in the study, takes into consideration the scientific community with whom the study is supposed to establish a dialog. Thus, the researcher must respect the criteria and parameters used by the scientific community regarding the procedures for gathering and analyzing data (Fig. 2.13).

The techniques selected for presentation in this section include some that are commonly employed in studies undertaken in the field of management. The techniques for gathering and analyzing data encompass a series of instruments that are used by researchers in carrying out the activities planned for their investigations. The gathering and analysis of data can be performed in several ways according to the goals of the study being conducted as well as the research method being used.

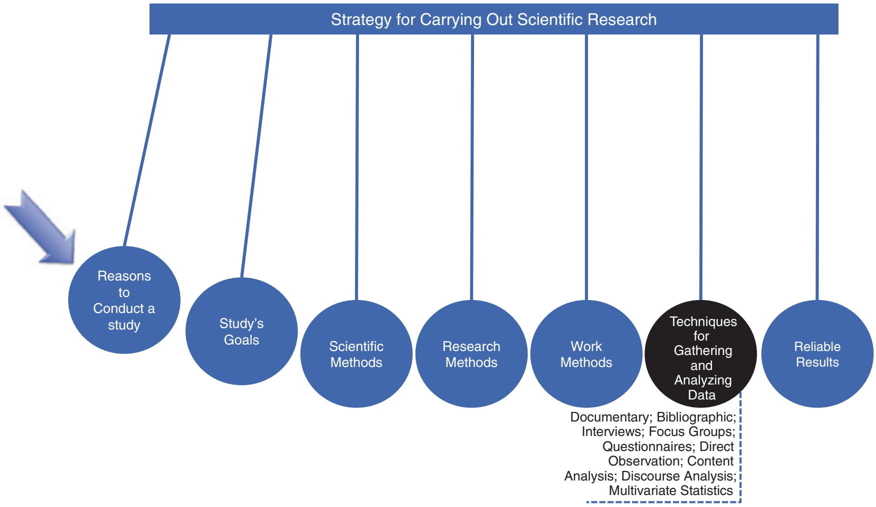


Fig. 2.13 Pendulum for conducting scientific research—techniques for gathering and analyzing data. *Source* Elaborated by the authors

Table 2.4 Techniques for gathering and analyzing data

Objective	Techniques
Data gathering	Documentary Bibliographic Interviews Focus groups Questionnaires Direct observation
Data analysis	Content analysis Discourse analysis Multivariate statistics

Source Elaborated by the authors

Next, some techniques for gathering and analyzing data that are recommended for the operationalization of the previously discussed research methods are presented. The goal of this presentation is not to detail the application of each technique but rather to provide an overview of the theme by noting the techniques that are usually applied in studies in the field of management. Table 2.4 presents the main techniques to be presented.

The foremost techniques for gathering data that are normally applied in studies in the field of management are presented next. This is a fundamental step in the research work and should be well planned and rigorously carried out to avoid biased or untrue conclusions.

One technique that can be used for gathering data is the documentary technique. Such a data-gathering technique is usually the first necessary step in the operationalization of a study because it allows the researcher to collect previous information on the topics to be studied (Saunders et al. 2012).

These documents may or may not be textual (pictures, audio or video recordings, etc.), and they may be classified as primary or secondary sources. Primary documents are those that are compiled or produced by the researcher him or herself. Secondary sources are those that have been transcribed from primary sources or, alternatively, recordings, pictures, and so on that have been used by the author but were produced by other people (Saunders et al. 2012).

Another technique used to gather data is the bibliographic technique. The goal of this technique is to provide to the researcher what has previously been developed on a given theme. Bibliographic research allows that which has been said or written about a given subject to be studied again under a new light, allowing the possibility for new discoveries on the subject (Saunders et al. 2012). To use this data-gathering technique, the researcher may use books, articles in scientific periodicals, and conference proceedings, among others.

A third technique for gathering data is the interview. The interview is a procedure that is often used to gather data, and its goal is to investigate a given situation or diagnose given problems. Interviews may be classified into two types (Dicicco-Bloom and Crabtree 2006):

- Standardized/structured: in this case, the interviewer defines and follows a pre-established script. The interviewer cannot adapt/modify the questions in response to the situation;
- Not standardized/not structured: the interviewee may develop the situations as he sees fit. Thus, the subjects may be explored in a broader manner. Questions are open and may be answered in an informal conversation.

Among the advantages of the interview, the foremost is that it is a flexible instrument through which questions may be rephrased to provide greater understanding of the gathered data (Saunders et al. 2012). When an interview is conducted in person, in addition to the verbal answers of the interviewee, it is also possible to observe his or her attitude toward the questions. Furthermore, the interview represents an opportunity to gather information that is not normally found in bibliographic sources.

Nevertheless, the interview also has some disadvantages, including possible difficulties in communication between the interviewer and the interviewee and difficulties interpreting questions and answers (Saunders et al. 2012). Another disadvantage is that during the interview, a bias may be introduced by the interviewer/researcher. Moreover, the interviewee may withhold important information, which the researcher has no control over.

Another way to conduct data gathering is by creating a focus group. The focus group has a qualitative nature and aims to understand the considerations made by a group of people after an experience, idea, or event (Plummer-D'amato 2008). The focus group can be perceived as an in-depth interview that occurs in groups with structured sessions that contemplate the proposal, the size, the components, and the procedure for conducting the group (Saunders et al. 2012).

According to Plummer-D'Amato (2008), one particular trait of the focus group in comparison with the classical interview is that it allows the participants to interact, and this interaction may allow some to influence the answers of others. To conduct a focus group, the researcher must first define (i) the members who will participate in the focus group; (ii) the content of the interviews; and (iii) how the moderator will interact with the participants, among others (Saunders et al. 2012).

When conducting a focus group, a researcher should pay attention to the time of each activity, making explicit and clear what should be done and what goal the researcher wishes to attain with the activity (Saunders et al. 2012). Despite being a technique for gathering data, the use of a focus group assumes that an in-depth analysis of what is obtained from its proceedings will be conducted. The analysis of a focus group's results should be performed systematically, focusing on the focus group's objectives (Saunders et al. 2012).

Another technique for gathering data is the questionnaire, which consists of the application of a series of questions to a respondent. It is recommended that the interviewee answers the questionnaire in writing, which should facilitate the later analysis of the answers by the researcher (Saunders et al. 2012).

Depending on the research goal and the technique to be used to later analyze the gathered data, the researcher may choose different forms of questions in a questionnaire. The types of questions can normally be classified into three categories: (i) open questions, which are used in investigations that aim for greater depth and precision. However, the interpretation and analysis of the results is more complex; (ii) closed questions, which present alternatives to the respondent and restrict their answers but at the same time eases the analysis of the data because of the objectivity involved; and (iii) multiple-choice questions, which are also closed questions, but which present more alternative answers to the respondents. Multiple-choice questions may elicit more detailed information about the object being studied (Saunders et al. 2012).

Finally, another option for data gathering is direct observation. This technique allows the researcher to identify some given traits of the phenomenon or system being studied that often go unnoticed by the individuals who are part of the system. Therefore, this technique is more suited for some studies even when compared with general interviews or questionnaires.

However, to be scientifically valid, the observations must be conducted in the context of a plan that is duly elaborated and followed by the investigator (Saunders et al. 2012). These observations may be performed in a structured or unstructured manner; the observer may or may not be an active participant; the observations may be performed individually or by a team; and, finally, the observations may be conducted in a real or controlled (i.e., laboratory) environment (Ander-Egg 1976; Saunders et al. 2012).

Some techniques for data analysis are presented next. It is in this phase that the researcher interprets the gathered data to obtain the results of the study.

One technique that can be used to analyze data is content analysis. According to Bardin (1993, p. 38), content analysis may be understood as "a collection of communication analysis techniques, which uses systematic and objective procedures for the description of messages' contents". This type of analysis aims to infer conclusions regarding the content of messages delivered by someone. The inference may answer (i) what caused the message, i.e., what led the person to emit this type of message, or (ii) what the consequences of this message are, i.e., what effects that the message will have (Bardin 1993).

In addition, content analysis is present in two important issues for scientific research: the rigor of objectivity and subjectivity (Capelle et al. 2003). Therefore, content analysis, in seeking to reduce the subjectivity commonly found in qualitative studies, elaborates both quantitative and qualitative indicators that may support the researcher in understanding and comprehending the messages being communicated (Capelle et al. 2003). Based on this understanding and deduction, the researcher is able to infer results about the object of study (Capelle et al. 2003).

It is worth noting that content analysis has two main functions: (i) a heuristic function and (ii) an administrative proof function. The objective of the heuristic function is to make research more robust, increasing the odds of the researcher making discoveries. Furthermore, the heuristic function aims to foster the conception of hypotheses when the investigation seeks content that has been little explored in other studies (Bardin 1993).

The objective of the administrative proof function, in turn, is to serve as proof in the confirmation of hypotheses (Bardin 1993). These hypotheses may be either in the form of questions or in the form of provisional statements (Bardin 1993). In addition, to meet its goals, content analysis must be systematized into three large phases, as presented in Fig. 2.14.

It is worth noting that although the phases presented in Fig. 2.14, content analysis itself is influenced by the goals of the study being conducted. Moreover, the research problem and the researcher's previous knowledge also influence how the

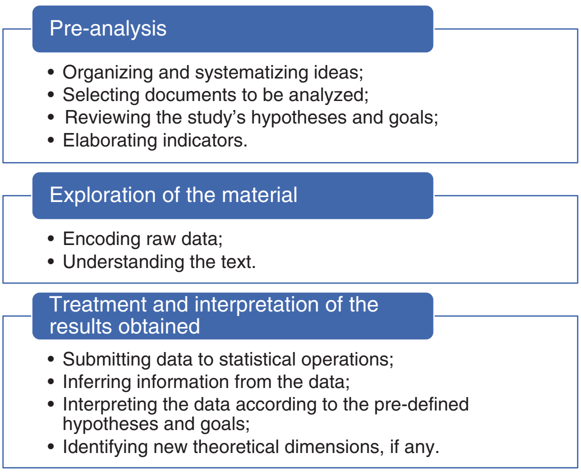
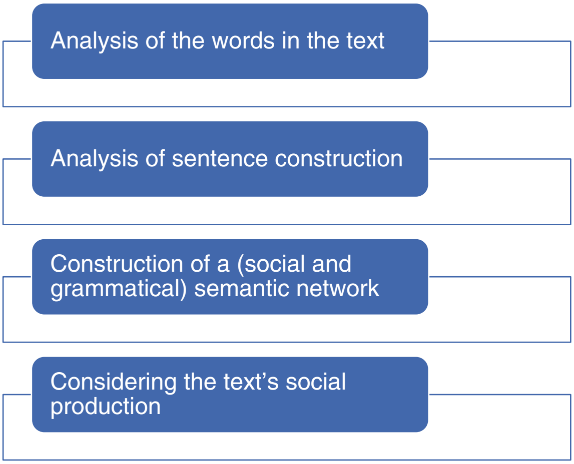


Fig. 2.14 Phases of content analysis. *Source* Elaborated by the authors based on Capelle et al. (2003)

Fig. 2.15 Steps in discourse analysis. *Source* Elaborated by the authors based on Capelle et al. (2003)



content analysis is carried out (Capelle et al. 2003). The researcher must therefore make decisions while executing this technique to obtain the best possible result in the analysis of his or her study's data.

Another technique that can be used to analyze data is referred to as discourse analysis. According to Minayo (1996), discourse analysis aims to understand the mechanisms that are seemingly hidden beneath the language. Moreover, discourse analysis is not a technique that seeks to describe or explain some phenomenon but rather to establish a criticism of something that already exists (Minayo 1996). Figure 2.15 presents the macro steps that are necessary to carry out discourse analysis.

It must be stressed that discourse analysis does not aim to understand or interpret what a text means but rather to understand how the text works in a given social and historical context (Capelle et al. 2003; Caregnato and Mutti 2006); i.e., discourse analysis addresses the meaning of the text and how it can influence a given environment or context (Caregnato and Mutti 2006).

Finally, the third technique that can be used to analyze data is multivariate statistics. The analysis of quantitative data by means of multivariate statistics is used to generate useful information from previously gathered data. The main purpose of this information is to guide the decision-making process and generate knowledge about a given problem or situation (Hair Jr et al. 2009).

According to Hair Jr et al. (2009, p. 23), "multivariate analysis refers to all statistical techniques that simultaneously analyze multiple measures of individuals or objects of investigation". However, for the researcher to successfully use multivariate analysis, certain directives must be taken into consideration. These directives are presented in Fig. 2.16.

Hair Jr et al. (2009) also state that there are several techniques that may be used to carry out multivariate analysis. It is not the present text's goal to describe each of these techniques in detail; nonetheless, among the foremost techniques, one

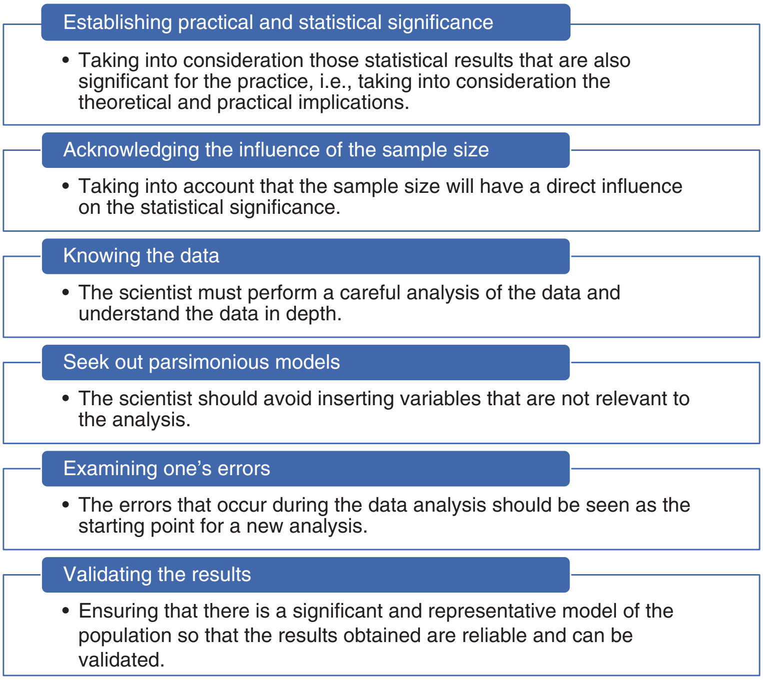


Fig. 2.16 Directives for the proper application of multivariate analysis. *Source* Elaborated by the authors based on Hair Jr et al. (2009)

may highlight multiple regressions and multiple correlations, multivariate analysis of variances and covariances, conjoint analysis, structural equation modeling, and confirmatory factor analysis (Hair Jr et al. 2009).

2.7 A Contextualization of Scientific Evolution

The preceding sections presented concepts related to scientific methods, research methods, and techniques for gathering and analyzing data. It is well known that these elements are fundamental to conducting research work. However, it is also important to consider how research works relate to one another and advance over time, which directly affects the trajectory of knowledge.

It is fundamental that the researcher considers how his or her work relates to other works over time and also that the researcher understands how research works affect the trajectory of science. Some authors have shown particular concern with science's trajectory rather than only on the research work itself.

This section presents a succinct description of science's trajectory from the perspectives of different authors. This description covers the main concepts of induction, deduction, the scientific paradigm (Kuhn's view), research programs (Lakatos' view), and anarchism (in light of Feyerabend).

2.7.1 The Origins of Knowledge Production: Induction and Deduction

When discussing the trajectory of science, it is interesting to start from what is known as "Hume's Problem", which can be described as follows:

(a) "All reasoning that refers to facts seems to be founded in a cause-and-effect relationship" (Hume 1999, p. 31);
(b) The cause-and-effect relationship is not known 'a priori';
(c) How is it possible to justify a passage that repeats itself several times as a universal reasoning and assertion?
(d) How can one justify the passage of temporal historical experience into causal reasoning?
(e) A causal relationship is not established by reasoning but rather "derives completely from habit and experience" (Hume 1999, p. 54);
(f) Hume's basic conclusion is that 'there is no rational justification for scientific laws'.

Therefore, Hume, the great skeptic of the eighteenth century, perceives the method in natural sciences as an effect-cause-effect logic (causal nexus). However, this causal nexus is considered in the context of induction and of a nonrational perspective. For the advocates of induction, the path toward scientific knowledge consists of proposing general conclusions based on a systematic collection of specific observations. This type of posture, which first appeared following Hume's thinking, is historically linked to a scientific tradition that is connected to empiricism and induction—the so-called empirical science.

It is worth noting the issue of language, which has been well developed within the inductive framework. One of the relevant points in the perspective of induction consists of making the meaning of each word clear; i.e., one must introduce as much conceptual precision as possible.

The relationship signifier/signified implies the possibility of a given word—a signifier—being understood in several different ways—the signifieds. For example, the meaning of the words (signifiers) mass, velocity, and acceleration are completely different if the proposed theory concerns classical or quantum mechanics. Therefore, for a scientific theory to be developed with the required precision, it is fundamental to define the different signifieds/signifiers that compose the theory in the clearest manner possible.

Hume's thinking was taken up again years later by Karl Popper. Popper starts from Hume, which is made clear in the following statement: "I approached the induction problem through Hume, whose statement that induction cannot be logically justified I considered to be correct" (Popper 2005, p. 72).

Popper develops his work criticizing the central idea of the theory proposed by Hume based on "repetition based on similarity" (Popper 1963, p. 27). According to Popper: "Independently of how many white swans cases we may observe, this does not justify the conclusion that all swans are white" (Popper 2005, p. 28).

This criticism of induction made by Popper is metaphorically depicted by Bertrand Russell, who describes the famous case of the "inductivist turkey". A given generic turkey learned that it was fed every day at 9:00 in the morning, and, because it was a "classic inductivist turkey", it drew (jumped to) certain conclusions: "I am always fed at 9:00 in the morning". However, its hypothesis revealed itself melancholically wrong when, on Christmas Eve, instead of being fed at 9:00 in the morning, it was beheaded. Therefore, an inductive inference with true premises (the turkey was fed everyday at 9:00 in the morning) led to a false conclusion (the turkey will always be fed, everyday, at 9:00 o'clock in the morning) (Chalmers 1999).

Popper's (1963) thoughts on 'Hume's problem' led the author to replace Hume's proposal with the perspective in which the scientist, instead of passively expecting that repetitions impose regularities on the world, actively seeks to impose regularities on it himself. This idea gave birth to Popper's Theory, which is based on a process of trial and error. According to this perspective, theories must be constructed based on a systematic logic of conjecture and refutation. Finally, an alternative method to induction for observing the causal nexus appears: the deductive perspective.

According to Popper, what takes place in science is a process that allows one to comprehend why our attempts to impose interpretations on the world logically came before similarities were observed (Popper 1963). Popper thus argues that scientific theories were not constructed from a composition of successive observations, as proposed by induction's advocates. In truth, theories and the construction of knowledge are conjectures that, if presented in a daring form and according to certain logical criteria, might be refuted if they do not properly fit empirical observations (Popper 1963). A necessary conclusion from Popper's proposal is that it must be possible to empirically refute theoretical conjectures (hypotheses).

This process of developing Popper's ideas leads to a discussion of the logical criteria required to develop a scientific study. In this sense, one must understand the so-called demarcation problem and falsifiability as a criterion of demarcation. Popper calls the "criterion of demarcation" the "problem of establishing a criterion that enables us to distinguish between the empirical sciences, on the one hand, and mathematics and logic, as well as metaphysical systems, on the other" (Popper 2005, p. 35). This problem had already been addressed by Hume, who attempted, for the first time, to measure it.

According to Popper, one can say that, to be part of science, a given hypothesis derived from a given conjecture must be falsifiable. In short, the method proposed by Popper demands that all proposed scientific hypotheses should be falsifiable by using empirical evidence.

Popper was strongly criticized with the advent of statistical theories, which apparently recommended a return to inductive logic. According to Popper, a probabilistic approach would apparently represent an insurmountable obstacle for a scientific theory based on deduction. According to Popper, "in fact, although probabilistic formulations may play a vital role in the field of empirical science, they reveal themselves in principle impossible to be strictly falsified" (Popper 2005, p. 471). However, Popper proposes that this argument is not sufficient to abandon the hypothesis of the causal nexus because the problem being approached is not deterministic but is instead stochastic because "the test of a statistical hypothesis is an operation of a deductive character—as are all other hypotheses" (Popper 2005, p. 471). Thus, "one first elaborates a test formulation so that it follows (or nearly follows) from the hypothesis" and has it later "confronted against experience" (Popper 2005, p. 471).

From these assumptions, Popper builds a logical method to test probabilistic hypotheses. Thus, "a probabilistic hypothesis can only explain statistically interpreted data and, as a consequence, can only be submitted to testing and corroboration by resorting to statistical summaries—and not by resorting, for example, to the 'whole existing evidence'" (Popper 2005, p. 472).

Thus, Popper seems to show that statistical methods (and, consequently, stochastic logic) are "in essence, hypothetical-deductive and operate by eliminating inadequate hypotheses, as all other methods of science operate" (Popper 2005, p. 472).

Another relevant point for discussion concerns the forms of capturing the so-called empirical evidence. In the context of the history of scientific development, it is important to perceive the role of the advancement of technology in the sense that it allowed some hypotheses to be empirically tested.

It just so happens that the scientific hypothesis that appeared with the emergence of Galileo's science could not be tested by direct sensory means (touch, smell, taste, vision, and hearing). For example, the technology of the telescope was fundamental to test the scientific hypothesis that the Earth revolved around the Sun. Thus, technological advances allowed phenomena to be observed not with the 'naked eye' but instead with an 'instrumented eye' or a 'technological eye'. Therefore, empirical tests must be considered from the possibility of using technologies for empirical testing that are compatible with the constructed hypotheses/models.

2.7.2 The Research Programs

Imre Lakatos developed his studies, like Kuhn, from a critical perspective of falsificationism and induction, proposing a structure entitled the Methodology of Scientific Research Programs, the purpose of which is to propose guiding solutions for the conduct of scientific research. To Lakatos (1970, p. 162), "Science itself as a whole can be considered as an immense research program with Popper's supreme heuristic rule: 'to construct conjectures that have greater empirical content than their predecessors'".

Moreover, scientific progress is made possible if the theories supporting it are well founded (Lakatos 1970). Therefore, the Methodology of Scientific Research Programs consists of methodological rules that seek to identify paths to follow in conducting research (positive heuristic) or paths to be avoided in conducting research (negative heuristic) (Lakatos 1977).

The negative heuristic is formed by a hard core that contains basic assumptions regarding the program; this core is protected from falsification due to a protective belt (Chalmers 1999). Lakatos (1970) claims that this protective belt is composed of a series of auxiliary hypotheses that aim to protect the program's irreducible core.

The positive heuristic, in turn, is composed of a collection of suggestions for "how to change and develop the 'refutable variants' of the research program, and how to modify and enhance the 'refutable' protective belt" (Lakatos 1970, p. 165). The goal of this heuristic is to prevent some irregularities found in the program from confounding the researcher (Lakatos 1970). The positive heuristic also presents a series of models that simulate reality (Lakatos 1970).

According to Lakatos (1977) in his methodology, scientific conquests belong to respectable investigation programs that can be evaluated according to their contributions to a given problem. When one research program overtakes another, a scientific revolution takes place (Lakatos 1977). The research program progresses by modifying the protective belt, and, in this way, opportunities for new discoveries appear to encourage the program's progress.

2.7.3 Research Paradigms

In his book The Structure of Scientific Revolutions, Thomas Kuhn (1967) presents the idea that neither the inductivist nor the falsificationist approach provide for a historical confrontation of their theories (Chalmers 1999). Therefore, the theory proposed by Kuhn (1967) emphasizes the advancement of science in the sense that when a scientific revolution occurs, some theoretical concept is abandoned and is replaced by another concept that seems to be more adequate in that historical moment. Chalmers (1999) depicts the perspective of scientific advancement proposed by Kuhn in Fig. 2.17.

Pre-science is what takes place when scientific activity occurs in a disorganized manner; i.e., it is not yet taking place within a specific paradigm. In this pre-science phase, there is no agreement among scientists on what or how to do research (Chalmers 1999).

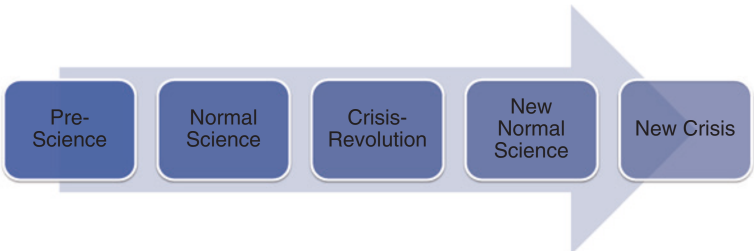


Fig. 2.17 Advancement of science according to Thomas Kuhn. *Source* Elaborated by the authors based on Chalmers (1999, p. 135)

After pre-science, there is a stage of normal science, which Kuhn (1967) defines as the stage in which a paradigm exists, and it is responsible for determining what is science and what is not, i.e., what is or is not relevant for research. When normal science begins to fail due to insufficient or inadequate explanations for some phenomena, the period termed a "crisis" begins. The crisis period lasts until a new paradigm is defined and, with it, a new normal science (Chalmers 1999).

It is worth clarifying the paradigms as defined by Kuhn (1967, p. 13): "universally recognized scientific achievements which, for some length of time, provide model problems and solutions to a community of science practitioners". These paradigms' rules are responsible for governing science when science is understood as the activity responsible for solving both theoretical and experimental problems (Kuhn 1967).

It is important to stress that to Kuhn (1967), to be considered valid in the scientific milieu, a new theory should be backed by its applications, and the solutions to problems should be tested in reality or in laboratory trials.

2.7.4 Epistemological Anarchism

In his work, "Against Method", Feyerabend (1975) claims that no scientific method is adequate because even if researchers try to follow rules in conducting their research work, they end up breaking some of the rules to ensure that there is scientific advancement from their investigations. He further claims that his goal "(…) is not to replace a set of rules with another set of the same kind: my goal is, rather, to convince the reader that all methodologies, including the most obvious ones, have limitations" (Feyerabend 1975, p. 43).

To Feyerabend (1975), the only valid rule in carrying out research work is that "anything goes." He claims that all scientific methods that have been proposed have failed at providing rules to guide scientific activity. Furthermore, Feyerabend stands out from other scholars of science because he does not subscribe to the superiority of science over other forms of knowledge (Chalmers 1999).

According to Feyerabend (1975), "The idea that science can and should be governed according to fixed and universal rules is at one time non-realistic and damaging. It is non-realistic because it assumes a far too simple view of man's talents and of the circumstances that encourage or cause its development. It is damaging because the attempt to enforce rules will necessarily increase our professional qualifications at the cost of our humanity. Moreover, the idea is harmful to science because it neglects the complex physical and historical conditions that influence scientific change. They make science less adaptive and more dogmatic" (Feyerabend 1975, p. 120).

In his main argument, the author criticizes the notion of the existence of a 'unique' universal scientific method and the existence of a central logic that answers, from the epistemological perspective, the construction of scientific theories. To corroborate his statement, Feyerabend cites Einstein when he says, "the external conditions that experience facts put [before the scientist] do not allow him, in erecting his conceptual world, to hold too tightly onto a given epistemological system. As a consequence, the scientist will appear, to the eyes of an epistemologist that holds on to a system, as an opportunistic and unscrupulous person…" (Feyerabend 1975, p. 20). Thus, the author proposes that "a complex medium, in which there are surprising and unforeseen elements, calls for complex procedures and challenges an analysis based on rules that were set beforehand…" (Feyerabend 1975, p. 20). It may be concluded from Feyerabend's explanations that the complexity of the phenomena that exist in reality requires flexible and plural method(s). For a complex reality, it is necessary that one does not depend exclusively on 'one single and better way' to investigate a problem at hand. In the words of Feyerabend, "the scientist must adopt a pluralist methodology. He must compare ideas first to other ideas instead of to 'experience', and he should try first to perfect rather than remove those concepts that are defeated in the confrontation" (Feyerabend 1975, p. 40).

Thus, Feyerabend (1975) proposes, as the only viable rule for science, the Anything-Goes logic. However, the notion of Anything-Goes should not be understood as an attempt to replace the themes identified by the Popperean School ('the falsificationism school'), by inductivism, or by the research programs proposed by Lakatos (Feyerabend 1975). The concept of Anything-Goes should be understood as a means to pluralize and make flexible the use of a method that implies the possibility of joint usage of the many currents that elaborate on the 'scientific method', as well as using other methods that are not cataloged as scientific but that may aid in the objective and concrete investigation of problems.

2.7.5 The New Production of Knowledge

Some criticism regarding the traditional scientific approach, and as a consequence the existing methods cited so far, can be addressed. Romme (2003) states that there is some difficulty in adapting the models used by the natural sciences to studies aimed at organizations.

Romme's (2003) criticism regarding the application of the social sciences to studies of organizations mainly concerns the large amount of discussion about epistemological issues and that little attention is paid to the researchers' objectives. The researchers' objectives are to understand the problems of the organization and, most importantly, to propose solutions to these problems (Romme 2003).

Seeking to overcome this difficulty in conducting studies in the field of management with the natural or social sciences approach, Gibbons et al. (1994) suggest that studies in this field make use of broader and more abstract knowledge. Such knowledge is aimed at building knowledge that is applicable to an organization. This type of knowledge is labeled as Mode 2. According to Romme (2003), research work conduct within an organization is best carried out when one has a less individual and a more pluralistic perspective in terms of methods. However, it is a common conclusion that knowledge production takes place through the application of the classical logic of the scientific disciplines, such as physics, chemistry, or biology. According to Gibbons et al. (1994), these disciplines represent the paradigm for the production of scientific knowledge.

Note that although these two types of knowledge production have their own particularities, there are interactions between them. In addition, the production of Mode 2 knowledge does not replace Mode 1: it completes it. However, the research work carried out currently uses markedly more Mode 1 knowledge than Mode 2 (Gibbons et al. 1994; Starkey and Madan 2001; van Aken 2004, 2005).

Mode 1 knowledge refers to a form of knowledge production with a disciplinary perspective; i.e., it represents the traditional production of knowledge (Burgoyne and James 2006; Gibbons et al. 1994). Problems studied with the Mode 1 approach to knowledge are solved in a context in which academic knowledge prevails, and there is no great concern regarding the practical applicability of the knowledge generated (Gibbons et al. 1994; Starkey and Madan 2001; van Aken 2004, 2005).

In fact, the production of Mode 1 knowledge, because it is disciplinary, usually distinguishes between fundamental knowledge and applied knowledge. Specifically, fundamental knowledge is founded on existing theoretical bases, whereas applied knowledge is founded on engineering and is concerned with the real use of knowledge (Gibbons et al. 1994; Starkey and Madan 2001; van Aken 2004, 2005).

Because of the characteristics of Mode 1, research work conducted under its precepts usually has no immediate potential for application (Burgoyne and James 2006), which is one of the limitations that leads some authors to consider developing their research work using the precepts for producing Mode 2 knowledge (van Aken 2005; Burgoyne and James 2006; Gibbons et al. 1994).

As a consequence, Mode 2 knowledge can be explained as a system for producing knowledge that focuses on its application; i.e., it covers all of the production of knowledge for the advancement of science up to knowledge that can be applied for the solution to the real problems of professionals inside organizations (Burgoyne and James 2006).

Gibbons et al. (1994) claim that Mode 2 knowledge rejects a linear view of knowledge transference. The knowledge that is produced must have a constructivist approach, and transdisciplinarity is the key point for its advancement. Transdisciplinarity, in this context, can be perceived as the knowledge that arises from the application's context itself. Thus, transdisciplinarity may have its own theoretical structure and specific research methods that cannot always be visualized in the traditional production of knowledge (Mode 1) (Gibbons et al. 1994; Starkey and Madan 2001; van Aken 2004, 2005). The concepts related to the production of Mode 2 knowledge will be explored in greater depth in the next chapter.

Once the main characteristics of the traditional sciences have been presented along with their trajectory over time, concepts related to the main theme of this book, Design Science, must be introduced. Therefore, the next chapter presents some of the criticism of the traditional sciences, the history of Design Science, and the main concepts related to it.

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Chapter 3
Design Science—The Science of the Artificial

> *Will it be legitimate to shelter longer in the epistemological shade—itself, henceforth uncertain—of the old and little questioned scientific disciplines?*
>
> (Le Moigne 1994, p. 72)

This chapter addresses the central concepts of Design Science, as well as the history and evolution of this science over time. The main authors who criticize traditional science and propose the use of Design Science to guide research focused on problem solving and artifact designing are cited. In addition, the main areas dealing with the study and application of Design Science as a research paradigm are explained.

In the context of this study, *design* consists of the activity of making changes to a given system, transforming situations to achieve improvements. The activity of making changes is performed by a human being who, to do this, applies the knowledge to create, i.e., develop, artifacts that do not yet exist (Simon 1996).

Simon's book *The Sciences of the Artificial* was first published in 1969 and introduced the expression "Science of Design," which later was renamed "Design Science" (van Aken 2004; March and Smith 1995; Romme 2003; Venable 2006). When translated into Portuguese, different forms for this term are found, such as Sciences of the Artificial, Science of Design and even Engineering Science (Le Moigne 1994, 1995; Simon 1996). In this book, the term *Design Science* will be maintained and used.

In his seminal work, Simon (1996) differentiated natural from that which is artificial, in which the latter can be understood as something that was produced or invented by human beings, who are influenced by this product. As examples of what is artificial, machines, organizations, economy, and even society could be cited. For Simon (1996), the sciences of the artificial should be concerned with how things should be to achieve particular goals, by either solving a known problem or designing something that does not yet exist. Indeed, designing is a functional characteristic of the sciences of the artificial (Simon 1996).

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A discussion of Design Science starts at the moment when a gap is identified in situations in which the traditional sciences have been exclusively used to conduct certain investigations. Studies focused on studying design, conception, or even problem solving cannot support themselves exclusively on the paradigm of the natural and social sciences. This inability occurs mainly because the objectives of traditional sciences are to explore, to describe, to explain and, when possible, to predict (van Aken 2004; Romme 2003).

However, some studies might have other objectives, such as prescribing solutions and methods for solving a given problem or even designing a new artifact. According to van Aken (2004), a science that aims to prescribe a solution can help reduce the existing gap between theory and practice. Thus, research that results in a prescription has easier application, including by the professionals of organizations, and it can also promote the recognition of its relevance to the practical field (van Aken 2004).

It is in this context that Design Science positions itself, i.e., as an epistemological paradigm that can guide research toward problem solving and artifact design. Therefore, this chapter will focus on Design Science as a central subject, and it is organized into three sections.

3.1 Criticism of the Traditional Sciences

Research conducted under the paradigm of traditional sciences, such as the natural and social sciences, results in studies that focus on explaining, describing, exploring, or predicting phenomena and their relationships with each other (van Aken 2004; Gibbons and Bunderson 2005; Manson 2006). However, the traditional sciences can have limitations when the goal is to study the design, construction, or creation of a new artifact, i.e., something that still does not exist, or to conduct research focused on problem solving. It is based on these premises that the traditional sciences are criticized, and the use of the Design Science is recommended as a new epistemological paradigm for conducting research (van Aken 2004; March and Smith 1995; Le Moigne 1994; Romme 2003; Simon 1996).

Simon (1996) argued that the natural sciences constitute a body of knowledge about a given class of objects and/or phenomena in the world (their characteristics and how they behave and interact with each other). Therefore, the tasks of natural scientific disciplines are to search and explain how things are and how they work. This reasoning can be applied to both natural phenomena (biology, chemistry, physics) and social phenomena (economics, sociology) (Simon 1996).

Because of the limitations of the traditional sciences previously presented, Simon (1996) discussed the need to introduce a science that is dedicated to proposing ways of creating (constructing and evaluating) artifacts that have certain desired properties, i.e., how to design artifacts. This is the "The Science of Design" or Design Science. Similarly, Le Moigne (1994) emphasized the need for a science that breaks Cartesian barriers. From this breakup, knowledge could be built from the interaction between the observer and the object of study, "considering knowledge more as a built project than a given object" (Le Moigne 1994, p. 72).

Moreover, Simon (1996) criticized traditional science, stating that it could not be considered the only source for building knowledge. This criticism is justified by the world being much more artificial than natural. Thus, a science that only engages in explaining natural phenomena is insufficient for the progression of science and of knowledge in general (Le Moigne 1994).

Moreover, traditional science is concerned with generating knowledge about things that already exist. This knowledge is developed through the analysis of phenomena and objects. However, Simon (1996) questioned how to generate knowledge about things that do not yet exist and even how to design objects or systems that do not exist.

This criticism developed in the sense that the central objectives of traditional science are to describe and explore, which, while important, are insufficient for designing or creating systems that do not yet exist (Romme 2003; van Aken 2005). Accordingly, March and Smith (1995) emphasized the importance of a science that is also able to support the construction and evaluation of new artifacts. The concept and characterization of artifacts will be topics detailed in a later chapter.

Romme (2003), in turn, questioned the exclusive use of traditional science concepts to conduct research into organizational areas. His fundamental criticism regarded the lack of relevance of studies conducted under the natural and social sciences paradigms. Romme (2003) emphasized that traditional science does not contribute to reducing the gap that exists between theory and practice. This fact occurs because the generated knowledge has a highly exploratory and analytical character, which does not significantly contribute to the use of such knowledge in real situations.

Similar to Romme (2003), van Aken (2004) expressed his concern with research conducted only under the traditional science paradigm. Simply understanding a problem is often not sufficient to solve it; thus, the study and development of a science, focused on solving real problems and creating artifacts that can contribute to improve existing systems or even new systems, are essential (van Aken 2004).

Le Moigne (1994, p. 72) expressed his discontent with and distrust of traditional science when he stated that the "suffocating Cartesian dualism" should be avoided. Le Moigne (1994) even argued for the need for interaction between the study object and the observer. This interaction would enable the real construction of knowledge and not simple observation of a given reality (Le Moigne 1994). Table 3.1 presents a summary of some of the criticisms of traditional science by the authors cited in this book.

Table 3.1 does not seek to be exhaustive. The goal of the table is to expose the main criticisms of traditional science from the point of view of the authors who proposed the use of Design Science as a possible solution to close the existing gaps, particularly in the natural and social sciences. The next section will present the history of Design Science, considering the time period during which the authors can be found, as well as the areas in which the application of this science is being proposed and studied.

Table 3.1 Main criticisms of traditional science

Criticism	Simon (1996)	Romme (2003)	March and Smith (1995)	Le Moigne (1994)	van Aken (2004, 2005)
The world in which we live is more artificial than natural, and thus, a science that addresses the artificial is required	X			X	
The traditional sciences are not dedicated to the design or study of systems that do not yet exist	X		X		X
There is a lack of relevance of the research conducted exclusively under the traditional science paradigms		X			X
The proper construction of knowledge must occur from the research process, which includes interaction between the object and observer				X	

Source The authors

3.2 History of Design Science

Herbert Simon is considered a pioneer in the discussion of Design Science. Simon inspired the distinction between exploratory sciences (traditional science) and the sciences of the artificial—Design Science—in his seminal work on this subject, *The Sciences of the Artificial,* published in 1969 (van Aken 2004; Horváth 2004; Manson 2006; Pandza and Thorpe 2010; Vaishnavi and Kuechler 2009). The argument used by Simon to differentiate these sciences was that understanding phenomena, systems, and problems is not sufficient (van Aken 2004). In other words, an explanation of how things are is insufficient. Instead, a science interested in how things should be is what is needed (Pandza and Thorpe 2010).

However, although the work of Simon (1969) is considered seminal to Design Science, the discussion of the importance of an alternative science, compared to traditional science, begins prior to 1969. Figure 3.1 shows the primary authors who contributed conceptually to Design Science and who are especially important for this book. The authors highlighted in the text were defined based on the analysis of their criticisms within the broader context of science, particularly regarding their contributions to Design Science.

In the fifteenth century, Leonardo Da Vinci began to understand the importance of the engineering sciences and started devising solutions to problems that renowned scientists (based on the fundamentals of traditional physics) had failed

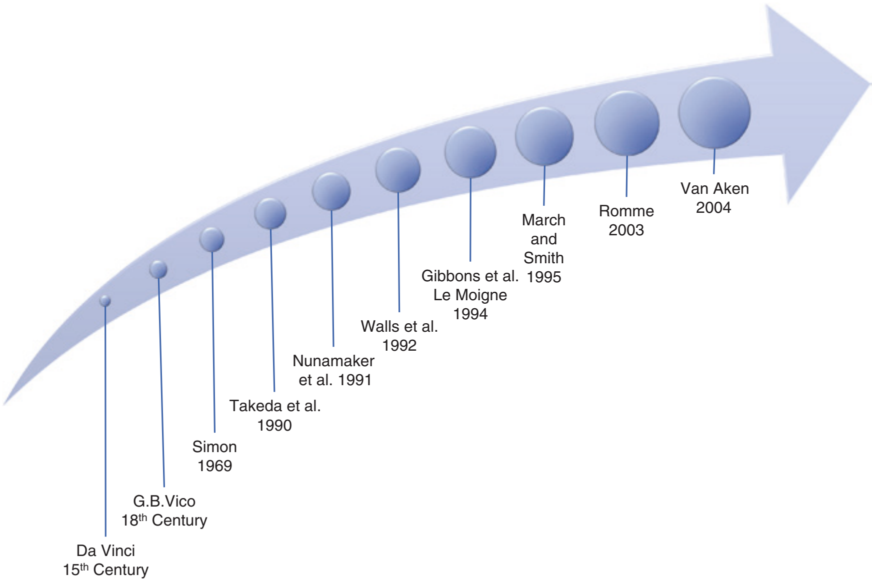

Fig. 3.1 Main authors who contributed to design science. *Source* The authors

to "discover" (Le Moigne 1994). Therefore, because traditional science had a more analytical view during this period, it received criticism and was limited to the generation of knowledge focused on solving problems and on the design and evaluation of artifacts.

One of these critics was Giovanni Battista Vico, who contributed to the development of what would become Design Science. Vico published his work between 1702 and 1725, but his ideas are still considered to be epistemological innovations. Vico (1981 *apud* Le Moigne 1994, p. 57) challenged "Cartesian reductionism" and suggested that scientific knowledge was grounded in the "science of imagination [*l'ingenium*]" and not in the analytical sciences.

This criticism was based on mainly the inventions introduced at that time (1708) not being successful when they were grounded only in the analytical sciences. That is, to succeed, the inventors of that time had to use a new science that was capable of supporting the construction and creation of new artifacts (Le Moigne 1994).

In the twentieth century, another text became relevant in the context of Design Science: *The Sciences of the Artificial* by Herbert Simon (1969). The concepts presented in this work received special attention when Simon *was awarded the Nobel Prize* in 1978 for his research into the decision-making process. The awarding of this prize to Simon promoted scientific recognition of his research in general and his epistemological manifesto in particular (Le Moigne 1994).

The Sciences of the Artificial, in addition to being recognized as a text that discussed epistemological fundamentals, is also considered a methodological manifesto because it "implicitly *desacralized* the exclusive primacy of the analytical or reductionist method" that forms the basis of the traditional scientific methods (Le Moigne 1994, p. 65).

Simon (1996) therefore proposed a new perspective on science, in which the design of knowledge is more important than the object of knowledge. That said, the conception of science proposed by Simon (1996) is different from that of the traditional sciences—analytical and reductionist—and thus attempts to propose a new epistemology, with a conception of Design Science that somehow "(…) make[s] the act of creating anything but a banal 'application' of a knowledge developed analytically elsewhere" (Le Moigne 1994, p. 228).

Another important contribution occurred in 1990, when Takeda et al. (1990) published the first article that sought to formalize a method for developing research focused on design. This article had a more technical and operational view regarding, for example, the process and construction of solutions to engineering problems. The central goal of Takeda et al. (1990) in this article was to develop a computational model that supported the development of intelligent Computer-Aided Design (CAD) systems.

Although Takeda et al. (1990) do not address the Design Science per se and do not even cite Simon (1996) in their text, they do present ideas similar to those of this author, though with a more applied and practical view. This method proposed by Takeda et al. (1990) and called Design Cycle thereafter inspired March and Smith (1995) and Vaishnavi and Kuechler (2009) to develop Design Science Research—a research method that operationalizes studies based on Design Science—which is a topic that will be explored in next chapter of this study.

In 1991, Nunamaker et al. (1991) undertook an important study for research in Design Science. Although it was targeted toward the Information Systems area, this text contributed later to the development of a research methodology for studies grounded in Design Science. It is worth noting that Nunamaker et al. (1991 did not use the concepts proposed by Simon (1996) and did not even use the term *Design Science* in their article—they opted for the term "engineering approach." Nevertheless, their contributions to Design Science are evident (Venable 2006).

Moreover, Nunamaker et al. (1991) introduced other elements in their article, such as "theorizing" or "theory building." This theory building strongly relates to the fundamentals of Design Science because the activity of producing theories also includes "development of new ideas and concepts, and construction of conceptual frameworks, new methods, or models" (Nunamaker et al. 1991, p. 94).

In the following year, Walls et al. (1992) proposed the application of Design Science concepts in conducting research and also in developing theories in the field of Information Systems. Walls et al. (1992) argued that, in addition to Design Science being fundamental to engineering, architecture, and the arts, it is also important to the Information Systems area because it enables the development of prescriptive theories. These prescriptive theories could contribute to the development of practical and effective solutions (Walls et al. 1992).

In this context of the construction of knowledge focused on practical applications, other authors, such as Gibbons et al. (1994), supported a new method of knowledge production: Mode 2. Mode 2 knowledge production is characterized by being more reflective. The various facets of the problem are considered, and several disciplines are used to construct new knowledge that is useful and applicable to those people who are interested in the research, i.e., it is relevant. This search for relevance is the principle that links Design Science concepts and Mode 2 knowledge production. (van Aken 2005).

Nevertheless, in 1994, Le Moigne (1994) published his work on Constructivism. In this work, Le Moigne (1994) presented what he called *new science*. This new science was based on the ideas of three authors: Simon, Piaget, and Morin—the Golden Triangle (Le Moigne 1994). The new science is characterized by being focused on conception and not exclusively on the analysis of the research object. It is a science more concerned with the process of knowledge construction than with the discovery of laws and immutable knowledge. It is noteworthy that in the research performed in the context of the new science, the object and the researcher are not separate; they actually interact, and this interaction is welcome (Le Moigne 1994).

In the following year, March and Smith (1995) proposed the application of the Design Science fundamentals to conducting research in the field of Information Systems and also to develop Information Technologies. This research was concerned with developing solutions that could support people in obtaining their goals, while also assisting in solving real problems. A characteristic of these authors is their proposal to integrate natural science and Design Science. While, on the one hand, Design Science should support the construction and evaluation of the artifacts, on the other hand, the natural sciences should construct explanations about this artifact (March and Smith 1995). This explanation, in turn, would be constructed through theorization and also justification of the developed theories (March and Smith 1995).

While in the 1990s, Information Systems was the most prominent area in the discussion about Design Science, in the 2000s, research into organizational management gained new prominence. Romme (2003) argued that traditional science contributes to understanding existing organizational systems; however, a science that contributes to creating new organizational artifacts is necessary. For this reason, Romme (2003) suggested that research in the organizational area be conducted based not only on traditional science but also on Design Science.

According to Romme (2003) research conducted in organizations is fragmented because, in most cases, it is performed by professionals or consultants within the organization and does not reach academia or appear in publications with greater reach. To mitigate this situation, Romme (2003) proposed that Design Science be used as the guiding principle for research in organizational areas, including by the scholars, because this principle would ensure the (practical) relevance of such research, as well as a broader reach of the results obtained.

However, a more rigorous approach in conducting such research is required for the scholars in the fields of management and Information Systems areas to use and recognize Design Science. Rigor is essential to ensuring that the products of research are easily teachable in academies and accepted for publication, ensuring greater interaction between the practical and theoretical realms (Romme 2003).

In 2004, while concerned about the relevance of research conducted in the fields of management and organization, van Aken (2004) published an article criticizing the research conducted under the traditional science paradigm. Thus, van Aken (2004) advocated the use of Design Science as an option for improving the relevance of research conducted in the area of management area. This

Table 3.2 Main authors and their central ideas about design science

Author	Proposition
Leonardo Da Vinci	He used engineering sciences to solve problems that, until then, the traditional sciences had failed to solve
G. B. Vico	This author contested "Cartesian reductionism" and proposed that scientific knowledge should be grounded in the "science of imagination [*l'ingenium*]."
Herbert Simon	He criticized the exclusive use of the analytical or reductionist method, argued that the design of knowledge is more important than the object of knowledge and proposed the use of design science
Takeda et al.	They discussed and made the first attempt to formalize a research method based on the concepts of design science
Nunamaker et al.	They sought to formalize a research method based on Design Science and exposed some of the research products supported by design science
Walls et al.	They advocated the use of design science concepts for conducting research, and they discussed the concept of prescriptive theories and their importance to the development of practical and effective solutions to existing problems
Gibbons et al.	They addressed a new mode of knowledge production, Mode 2, which would be more focused on the construction of relevant knowledge, produced in an application context and not only in academia
Le Moigne	He studied the new science: science focused on design and not only on the analysis of the research object
March and Smith	They advocated integration between design science and traditional science for conducting research focused on developing solutions
Romme	He discussed the use of the design science in the management field, states that a science that helps in the creation of new organizational artifacts is necessary and also discussed the rigor and relevant aspects of management research
van Aken	He was concerned with the relevance of research in the management field and in organizations in general and suggested the application of design science for conducting more relevant research; he stated that research should be prescriptive, which will facilitate its use by organizations, and also generalizable—science should be conducted not only to solve one problem in a given situation but also to solve problems of a certain class of problems

Source The authors

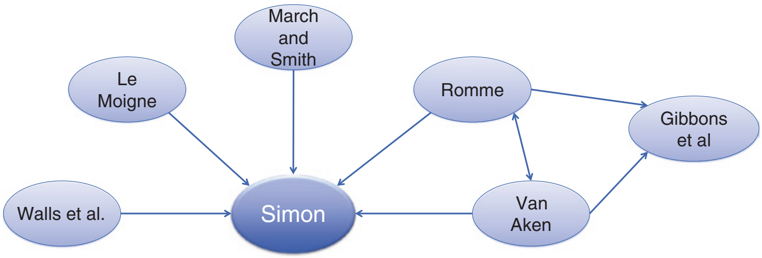

Fig. 3.2 Citations among the main authors discussed in this section. *Source* The authors

relevance would be high because this type of research would result in a prescription, which would help to solve real problems and to generate knowledge that could also be used in other situations, i.e., generalization.

Pondering on possibility of generalizing the knowledge that was produced to obtain a desired result in a given context and aiming then to apply it in other contexts, van Aken (2004) addressed the Technological Rule issue. The Technological Rule later evolved into Design Propositions—a generic template that can be used to develop solutions for a particular Class of Problems (van Aken 2011). Finally, Table 3.2 presents a summary of the authors that have been cited in this section and their central ideas about Design Science.

Figure 3.2 shows the connections, if any, between these authors throughout their texts. In some cases, they did not cite each other; however, a strong relationship between their ideas and propositions about Design Science is evident.

The main concepts of Design Science and its contextualization will be addressed in the next section. Furthermore, a comparison between the traditional science and Design Science will be presented, considering the body of knowledge of each.

3.3 Design Science and Its Structure

In *The Sciences of the Artificial*, Simon (1996) mentioned five areas of study as areas strongly related to Design Science: Engineering, Medicine, Law, Architecture, and Education. Therefore, it is noted that the Design Science has roots in engineering and also in other applied sciences. However, Information Systems was the area that exhibited faster development regarding the use of Design Science as an epistemological paradigm for the advancement of knowledge (March and Smith 1995; Nunamaker et al. 1991; Takeda et al. 1990; Walls et al. 1992).

Following areas such as engineering and architecture, researchers in Design Science also found an important epistemological and methodological contribution to conduct their research (Eekels and Roozenburg 1991). The 2000s were when Design Science started to be used by authors in the areas of management and organizations. The goal was to propose a science that could facilitate the conducting of research in the area and that considered not only rigor but also relevance (van Aken 2004, 2005; Romme and Damen 2007; Romme, 2003).

3.3.1 Fundamental Concepts of Design Science

The discussion of Design Science formally began with Simon (1969, 1996), who highlighted the importance of developing a science that is dedicated to the study of man-made artifacts and also to the study of how to design these artifacts to produce satisfactory results: "Design, on the other hand, is concerned with how things ought to be, with devising artifacts to attain goals" (Simon 1996, p. 198).

Artifacts in this context can be understood as things that are man-made, i.e., "artificial things can be characterized in terms of functions, goals, adaptation. Artificial things are often discussed, particularly when they are being designed, in terms of imperatives as well as descriptives" (Simon 1996, p. 28). Thus, "fulfillment of purpose or adaptation to a goal involves a relation among three terms: the purpose or goal, the character of the artifact, and the environment in which the artifact performs" (Simon 1996, p. 28).

Thus, "an artifact can be thought of as a meeting point—an interface in today's terms—between an 'inner' environment, the substance and organization of the artifact itself, and an 'outer environment,' the surroundings in which it operates" (Simon 1996, p. 29). Thus, the artifact is the organization of the inner environmental components to achieve goals in a particular outer environment (Simon 1996). The artifacts, as well as their types, will be addressed later in this text.

Furthermore, Design Science aims to create knowledge and not only to apply knowledge. When creating, knowledge about "how to design" is generated. In other words, Design Science is a science that focuses on design. Therefore, this science does not aim to discover natural or universal laws that would explain certain behaviors of the objects that are being studied but instead aims to understand the "(…) cognitive process by which the design that defines them was developed (…)" (Le Moigne 1995). Above all, Design Science is a science that seeks to develop and design solutions to improve existing systems, solve problems, or even create new artifacts that contribute to better human performance, whether in society or in organizations.

This conception is in agreement with the statements of van Aken (2005) regarding the goals of research performed under the Design Science paradigm, which seeks above all to produce knowledge that can be applied to solve real problems (van Aken 2005). Therefore, the nature of this type of research is often pragmatic and solution-oriented, i.e., knowledge must be built in the service of action (Romme 2003; van Aken 2004). However, it is essential to emphasize that although Design Science is focused on problem solving, it does not seek optimal outcomes (common to areas such as Operational Research). A satisfactory outcome for the context in which the problem is found is the aim (Simon 1996).

Simon (1996) differentiated an optimal solution (ideal) from a satisfactory solution as follows: “the decision that is optimal for the simplified approximation will rarely be optimal in the real world” (Simon 1996, p. 27). The decision maker can choose between optimal decisions in a simplified world or (good enough) decisions that are satisfactory in a world closer to the reality” (Simon 1996).

In this sense, solutions that are sufficient for problems in which the optimal solution is inaccessible or impractical to be implemented are sought (Simon 1996). This goal implies in clearly defining what satisfactory results are. The definition of a satisfactory result can be achieved in two manners: (i) consensus among the parts involved in the problem or (ii) advancement of the current solution, compared to the solutions generated by previous artifacts.

However, Design Science recognizes that problems in organizations tend to be specific. These specificities could somehow prevent generalizable knowledge. Indeed, van Aken (2004) argued that the solutions proposed by Design Science should allow for generalization of the prescriptions, i.e., they must be generalizable to a particular “Class of Problems”—a concept that will be discussed in subsequent chapters of this book.

However, Venable (2006) stated that research conducted under the Design Science paradigm not only proposes solutions to practical problems but can also contribute to improving theories. Theorization occurs with a new idea or as a concept for a new technology that can facilitate the solving of a problem (Venable 2006). This idea, which can support a theory, can be derived from different sources, as illustrated in Fig. 3.3.

These ideas, once they are developed through research, can contribute to improving theories. Such theories should be, above all, useful, i.e., they should present improvements to a certain technology or problem (Venable 2006). Regarding this utility, it is worth noting the importance of the concept of pragmatic validity for Design Science.

The premise of Design Science is that the research conducted under its paradigm, in addition to being rigorous and scientifically valid, should also seek pragmatic validity, i.e., utility. In this context, pragmatic validity seeks to ensure that the solution proposed to solve a particular research problem will, in fact, work, which will ensure the achievement of the expected results (van Aken 2011).

According to van Aken (2011), in addition to ensuring the utility of the proposed solution to the problem, pragmatic validity must also address other questions. Some of the questions that should be considered by the researcher are: (i) the costs and benefits of the solution; (ii) whether the solution meets the specificities of the environment/context in which it will be applied; and (iii) the needs of the parties interested in the proposed solution (van Aken 2011; Worren et al. 2002). Figure 3.4 summarizes the main Design Science concepts that were presented in this section.

Once the basic concepts of Design Science are explained, it is necessary to understand them, in comparison with the known concepts of traditional science. Therefore, the main differences and similarities between them will be presented in the next section.

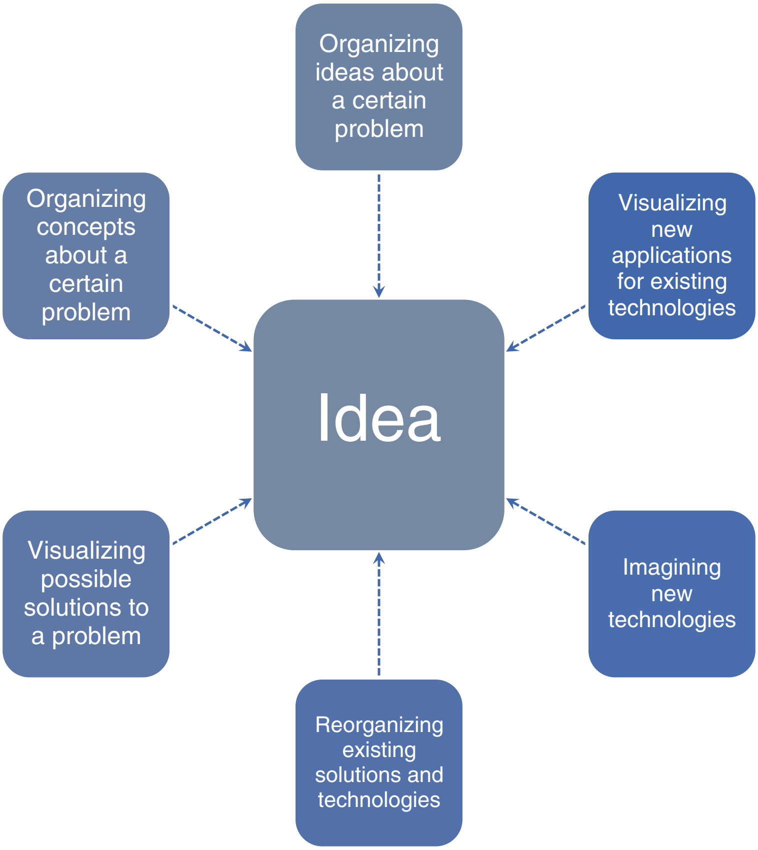

Fig. 3.3 Sources that can promote new ideas. *Source* The authors, based on Venable (2006, p. 15)

3.3.2 Comparison Between Design Science and Traditional Science

Although a comparison between traditional science and Design Science is required, it should be clear that they are not opposed to each other. They actually complement each other; they merely have different directions. Additionally, it is noteworthy that artifacts (the objects of study of Design Science) are inserted into nature, and "they have no dispensation to ignore or violate natural law" (Simon 1996, p. 24). The artifact does not even exist outside the natural world. It is actually an interface between the natural and artificial worlds (Le Moigne 1994).

The differences between these sciences can be observed when considering the products that they generate. While Design Science is focused on generating knowledge that supports problem solving and that has prescription as one of its products, the fundamental objectives of traditional science are exploring, describing,

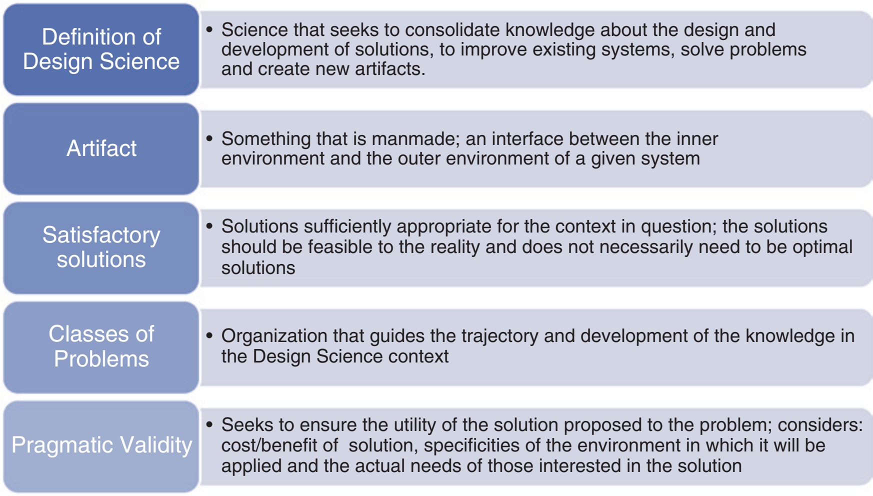

Fig. 3.4 Summary of the main design science concepts. *Source* The authors

Table 3.3 Distinctions between research focused on description and prescription

Characteristic	Research programs focused on description	Research programs focused on prescription
Dominant paradigm	Explanatory science	Design science
Focus	Problem focused	Solution focused
Perspective	Observation	Participatory
Typical research question	Explanation	Alternative solutions for a given class of problems
Typical research product	Causal model; quantitative law	Tested by and grounded in technological rules

Source Based on van Aken (2004, p. 236)

explaining and, when possible, making predictions about natural and social phenomena (van Aken 2004). It is noteworthy that van Aken (2004) made a distinction between description-driven research and prescription-driven research, and this distinction is analogous to the discussion between the natural and artificial sciences. Table 3.3 summarizes the distinctions proposed by van Aken (2004, p. 236).

The Design Science features presented indicate the possibility of using the fundamentals of this science for creating knowledge that is applicable to organizations. Romme (2003) analyzed the organizational research based on traditional science and how it could be developed when based on Design Science. Table 3.4 shows the main differences between traditional science and Design Science, as explained by Romme (2003, p. 559).

Romme (2003) noted that the view of traditional science increases understanding of phenomena "by uncovering the laws and forces that determine their characteristics, functioning, and outcomes" (Romme 2003, p. 558). Design Science, in turn, is

Table 3.4 Main differences between traditional science and design science

Categories	Traditional science (social and natural)	Design science
Purpose	Understand organizational phenomena, based on consensual objectivity, by uncovering general patterns and the forces that explain these phenomena	Produce systems that do not yet exist—that is, change existing organizational systems and situations to achieve better results
Model	Natural sciences (e.g., physics) and other disciplines that have adopted the scientific approach (e.g., economics)	Design and engineering (e.g., architecture, aeronautical engineering, computer science)
View of knowledge	Representational: our knowledge represents the world as it is; nature of thinking is descriptive and analytic; more specifically, science is characterized by: a search for general and valid knowledge; adjustments in hypothesis formulation and testing	Pragmatic: Knowledge in the service of action; the nature of thinking is normative and synthetic; more specifically, design assumes that each situation is unique, and it draws on purposes and ideal solutions, systems thinking and limited information; moreover, it emphasizes participation, discourse as a medium for intervention and pragmatic experimentation
Nature of objects	Organizational phenomena as empirical objects, with descriptive and well-defined properties, that can be effectively studied from an outsider position	Organizational issues and systems as artificial objects with descriptive, as well as imperative, ill-defined properties, requiring nonroutine action by agents in insider positions in the organization; imperative properties also draw on broader purposes and ideal target systems
Focus of theory development	Discovery of general causal relationships among variables (expressed in hypothetical statements): is the hypothesis valid? The conclusions stay within the boundaries of the analysis	Does an integrated set of design propositions work in a certain ill-defined (problem) situation? The design and development of new artifacts tend to move outside the boundaries of the initial definition of the situation

Source Adapted from Romme (2003, p. 559)

responsible for designing and validating the systems that do not yet exist, creating, recombining, or even changing products/processes/software/methods aimed to improve existing situations (Romme 2003).

Given the conceptual differences between these sciences, the structure for the production of knowledge, when grounded in Design Science is different from the structure used by traditional science (Chap. 2, Fig. 2.2). Figure 3.5 shows the structure for the production of knowledge, now from the Design Science point of view. Again, the representation of Newton's pendulum is used to illustrate the relationships and dependencies between each of the steps that should be considered in conducting scientific research.

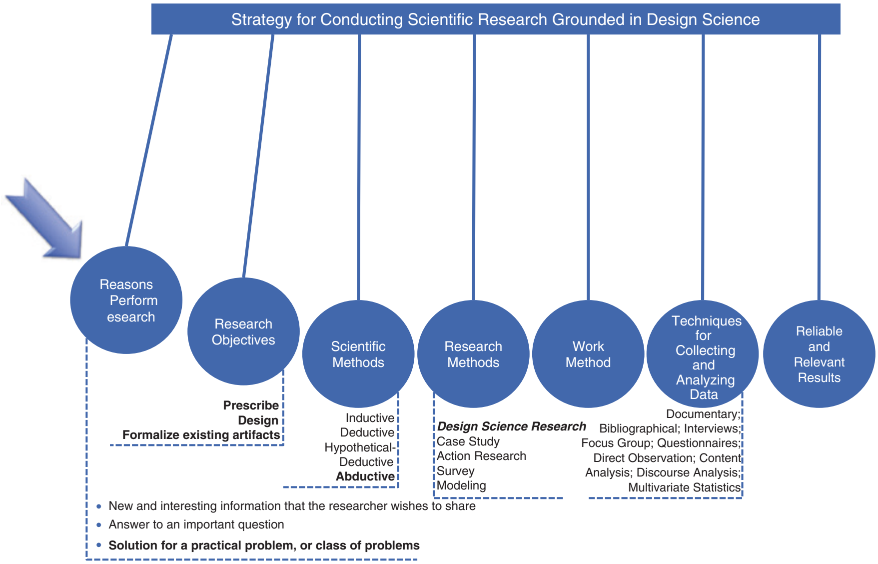

Fig. 3.5 Pendulum for building knowledge grounded in design science. *Source* The authors

The starting point for research conducted under the traditional science paradigm might be either a theoretical problem (a gap in existing theory) or an observation of reality that leads to a question. In Design Science, research usually starts from the need to design or build a given artifact. Additionally, the researcher can demonstrate the need to formalize or develop an artifact when observing reality. The research objectives are also different: while traditional science is concerned with exploring, describing, explaining, and possibly predicting, Design Science is concerned with prescribing solutions and designing or formalizing artifacts.

What is common between these sciences is that in both traditional science and Design Science, research should be conducted based on the foundations of scientific methods. Nevertheless, while in the traditional sciences the inductive, deductive, and hypothetico-deductive scientific methods are commonly used, a fourth scientific method is included in Design Science: the abductive method (Fischer and Gregor 2011; Lee et al. 2011; Vaishnavi and Kuechler 2009).

The abductive method consists of studying facts and proposing theories to explain them. Thus, abduction is a process of creating explanatory hypotheses for a given phenomenon/situation. At a later stage, other scientific methods can be used to test these hypotheses.

Abduction is considered a process that is, above all, creative. Because of this feature, it is the most indicated method for understanding a situation or problem, exactly because of the creative process intrinsic to this type of reasoning. Moreover, it is the only scientific method that enables the introduction of a new idea (Fischer and Gregor 2011). Peirce (1975) emphasized that abductive reasoning is characteristic of revolutionary scientific discoveries. Figure 3.6 provides a brief

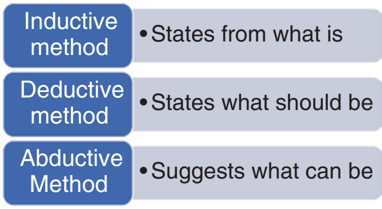

Fig. 3.6 Function of each scientific method. *Source* The authors

summary of what could be considered the core function of each scientific method to clarify better what the abductive method would be.

That Design Science uses abduction in conducting its investigations does not mean that traditional scientific methods are not used. However, they have certain limitations in Design Science. For this reason, research conducted under the Design Science paradigm tends to be driven by more than one scientific method, according to the step that is being developed and the goal to be reached.

That is, if the step that is being developed requires activities and creative reasoning on the part of the researcher, the application of the abductive method is appropriate. The abductive method is needed, for example, when the researcher is proposing possible solutions to solve the problem that is being studied. However, if the research step requires logical reasoning to evaluate certain aspects of an artifact, for example, the deductive method is most suitable. In this case, the researcher uses previous knowledge to build and evaluate the artifact that is under development.

It is worth noting that when the epistemological paradigm is Design Science, another research method arises: Design Science Research. Design Science Research, unlike other research methods, seeks to produce knowledge in the form of a prescription or a design. A prescription supports the solving of a particular real problem, while a design builds a new artifact.

However, research methods based on traditional science can also be applied under the Design Science paradigm. Thus, it is possible to conduct a case study based on the Design Science paradigm, in which the goal of the researcher is, for example, to formalize or evaluate an existing artifact. This concept will be explored in the following chapters.

Nevertheless, the knowledge generated from research grounded in Design Science is different from traditional knowledge because it is focused on being relevant, in addition to being rigorous. That is, the knowledge generated must be recognized by the academic community, and it should simultaneously be useful for professionals, generating satisfactory solutions.

Thus, purely academic and disciplinary knowledge (Mode 1), commonly found as the product of traditional science, can evolve into transdisciplinary knowledge, which can also extend and be relevant outside of the academies. This transdisciplinary quality is why research conducted under the Design Science paradigm is important.

It is exactly in the context of the building of knowledge that is transdisciplinary and more concerned with the development of useful knowledge in the application domain that Gibbons et al. (1994) sparked the discussion regarding Mode 2 knowledge production. Knowledge production grounded in Mode 2 must be considered as a model to be followed by research conducted in Design Science (van Aken 2004; Romme 2003). In this context, the interaction between the researcher and research subject is even welcome. Moreover, the concern with the generation of useful knowledge for professionals helps to overcome the walls of academia, thus expanding the scope of knowledge generated by researchers.

Given these concerns, Mode 2 knowledge is produced in the application domain. This domain can correspond to industry, government, or even society (Gibbons et al. 1994). Moreover, knowledge starts being produced when someone expresses an interest in the subject to be studied.

The production of Mode 2 knowledge occurs in the application domain, in which researchers meet to solve a given problem. Mode 2 Knowledge, once produced, exceeds the limits of academia and is transdisciplinary. That is, Mode 2 Knowledge is not linked to a single discipline; rather, it unites interests and diverse players. Moreover, for this type of knowledge to be built, different professionals with different expertise must often work together to achieve the best possible outcomes (Burgoyne and James 2006; Gibbons et al. 1994; Hughes et al. 2011; Starkey et al. 2009; Starkey and Madan 2001; van Aken 2004, 2005).

This union of different professionals from different areas to solve problems common to the group results in positive heterogeneity, in which each member makes contributions from the area in which he/she has the greatest knowledge or skill. Moreover, the integration between various professionals leads to a more reflective attitude toward the problem. Gibbons et al. (1994, p. 07) stated that "working in the context of application increases the sensitivity of scientists and technologists," and everyone is thus more aware of the consequences of what they are doing. In addition, the production of Mode 2 knowledge leads to more professionals helping to build and use knowledge, not only those people who are parts of universities.

However, to validate the knowledge produced, its quality must be considered in both the practical and academic senses. For this consideration, some economic and political requirements must be considered, in addition, of course, to the scientific requirements that are also common to traditional studies (Mode 1 knowledge production). Some questions should be asked to assess the quality of the knowledge that has been produced, for example, whether the solution is competitive in the market, whether it is socially appropriate or whether it actually answers the initially raised questions (Burgoyne and James 2006; Gibbons et al. 1994; Hughes et al. 2011; Starkey et al. 2009; Starkey and Madan 2001; van Aken 2004, 2005).

Finally, it is possible to state that the production of Mode 2 knowledge occurs and can be observed in many environments, including multinational environments, networks of companies, small businesses that work with high technology, government institutions, universities, laboratories, institutes, and research programs, among others (Burgoyne and James 2006; Gibbons et al. 1994; Hughes et al. 2011; Starkey et al. 2009; Starkey and Madan 2001; van Aken 2004, 2005). However, for produced knowledge to be recognized by both the academies and professionals in companies, research that results in this type of knowledge should be undertaken with the appropriate methodological rigor, and it should also consider its relevance as a key factor in its development. These methods are the only ways to reduce the existing gap between academia and organizations and their professionals.

That said, it is clear that the fundamentals of Design Science can contribute greatly to producing knowledge that would be more relevant and applicable and that would receive proper recognition from academia. However, for that recognition to occur, the use of a research method that adequately operationalizes the concepts of Design Science is required. Design Science research arises in this context and will be addressed in the next chapter.

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Chapter 4
Design Science Research

The body of design knowledge is rather fragmented and dispersed (…). Design research should therefore be redirected to more rigorous research, to produce outcomes that are characterized by a high external validity but that are also teachable, learnable, and actionable by practitioners.

(Romme 2003, p. 569)

This chapter presents the main concepts of design science research, which is a method that is conducted under the paradigm of design science to operationalize research. In addition to these concepts, the foundations for the application of design science research as a research method and the methods formalized by several authors for its operationalization are presented. A comparison of design science research with two alternate methods is performed. To prevent an exhaustive comparison in this book, we compare design science research with methods that are commonly used for qualitative research in Brazil: case study and action research.

4.1 Concepts and Foundations of Design Science Research

Design science is the epistemological basis for the study of what is artificial. *Design science research* is a method that establishes and operationalizes research when the desired goal is an artifact or a recommendation. In addition, research based on *design science* can be performed in an academic environment and in an organizational context.

Vaishnavi and Kuechler (2011) considered *design science research* to be a new idea or set of analytical techniques that enable the development of research in several areas. *Design science research* aims to study, research, and investigate the artificial and its behavior from an academic and organizational standpoint (Bayazít 2004). *Design science research* is a rigorous process of designing artifacts to solve problems, to evaluate what was designed, or what is working and to communicate the results (Çağdaş and Stubkjær 2011).

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Thus, *design science research* is a research method that is focused on problem solving (March and Storey 2008). Based on the understanding of the problem, this method can be used to construct and evaluate artifacts that enable the transformation of situations by changing their conditions to better or desirable states (March and Smith 1995; March and Storey 2008). The artifacts that are constructed or evaluated by *design science research* are classified constructs, models, methods, and instantiations (March and Smith 1995), which may result in an improvement of theories (Hevner and Chatterjee 2010; Venable 2006). These products of *design science research* are explored in the next chapter.

A key feature of *design science research* as a method is that it is oriented to the solving of specific problems to obtain a satisfactory solution for the situation even if the solution is not optimal. However, the solutions generated by *design science research* should be liable to generalization for a specific class of problems (van Aken 2004, 2005; Sein et al. 2011; Vaishnavi and Kuechler 2011). This generalization for a class of problems can enable other researchers and practitioners in various situations to use generated knowledge.

The application of *design science research* can potentially reduce the existing gap between theory and practice (van Aken 2004, 2005; Romme 2003) because this method is not only oriented toward problem solving but also produces knowledge that can serve as a reference for the improvement of theories. Figure 4.1 outlines *design science research* and the relationship between two essential factors for the success of the research: rigor and relevance.

As shown in the figure, *design science research* should consider the relevance of research to organizations. Professionals in organizations may use the results of these investigations and the generated knowledge to solve practical problems. Rigor should also be considered because it is an essential factor for research to be considered valid and reliable and can contribute to an increased knowledge base in a given area.

The knowledge base can be defined as the environment in which the researcher can determine which theories or artifacts were previously used or developed by researchers. The knowledge base is defined as the location where raw material for the development of new research and new artifacts are obtained (Hevner et al. 2004). However, this knowledge base is frequently insufficient for the development of new artifacts. Therefore, many researchers, for example, in the field of management, act in accordance with their own experiences or by trial and error when designing new artifacts.

The environment in Fig. 4.1 refers to the environment in which the problem is being observed, that is, where the phenomenon of interest to the researcher is obtained. The artifact operates in this context. This environment consists of persons, the organization and its technology (Hevner et al. 2004). Based on the observed organizational needs and problems of interest to the researcher, *design science research* can support the development and construction of artifacts and strengthen the existing knowledge base.

These artifacts subsequently undergo evaluations and justifications of their importance. To support these developments, construction, justification, and evaluation activities, the existing knowledge base needs to be consulted and employed. This

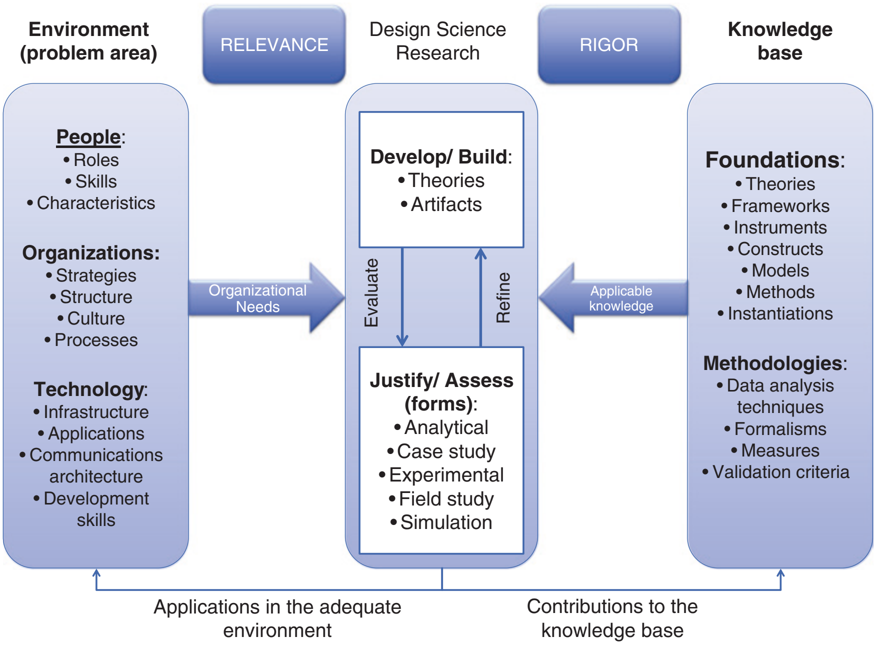

Fig. 4.1 Relevance and rigor in *design science research. Source* Adapted from Hevner et al. (2004)

knowledge base is composed of well-established foundations and methods that are recognized by the academic community. These methods primarily support the justification and evaluation activities of constructed artifacts or improved theory (Hevner et al. 2004).

To assist in *design science research*, Hevner et al. (2004) define seven criteria that should be considered by researchers. These criteria are essential because *design science research* demands the creation of a new artifact (criterion 1) for a specific problem (criterion 2). Once this artifact is proposed, its utility should be explained and the artifact must be adequately evaluated (criterion 3). The research contributions should be clarified for professionals interested in solving organizational problems and for the academic community to increase knowledge of the area (criterion 4).

To ensure the validity of the research and expose its reliability, it is essential that investigations are conducted with an appropriate amount of rigor to demonstrate that the constructed artifact is suitable for its proposed use and that it has satisfied the criteria for its development (criterion 5). To construct or evaluate the artifact, it is essential that the researcher conducts research to understand the problem and to obtain potential problem-solving methods (criterion 6). The research results should be properly communicated to all interested parties (criterion 7) (Hevner et al. 2004) (Fig. 4.2).

To ensure appropriate theoretical and practical contributions using the *design science research* method, March and Storey (2008) identified specific elements

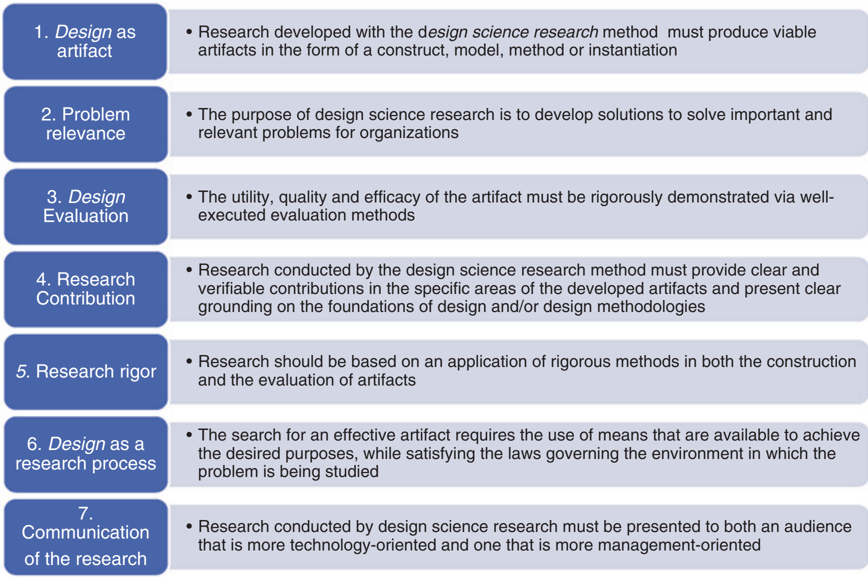

Fig. 4.2 Criteria for conducting *design science research. Source* Based on Hevner et al. (2004, p. 83)

that must be considered. Although March and Storey (2008) developed their studies in the area of information systems, the content addressed in their texts can be understood and adapted to other areas; management is one of the examples cited.

The first element raised by March and Storey (2008) that should be considered by *design science research* is the formalization of a relevant problem. The second key element is that the researcher must demonstrate the lack of suitable methods for solving the problem (March and Storey 2008) or the existence of better solutions to properly conduct research based on *design science*. In this manner, a researcher can justify the importance of the intended research.

A third element noted by March and Storey (2008) refers to the development and presentation of a new artifact that can be used to solve the problem. The fourth element identified by March and Storey (2008) is that the developed artifacts should be properly evaluated in terms of their utility and viability to demonstrate their practical and academic validity.

Another element that March and Storey (2008) suggest is critical for properly conducting *design science research* is that the research must ensure that value is added to existing theoretical knowledge (contributes to the advancement of general knowledge) and improve practical situations in organizations. The researchers should conclude their activities with an explanation of what was constructed and the implications of the research results for the practical field (March and Storey 2008).

The importance of research to the practical field is emphasized by Cole et al. (2005), who state that *design science research* is based on a pragmatic viewpoint that advocates the inability to separate utility from truth because “truth lies in utility”

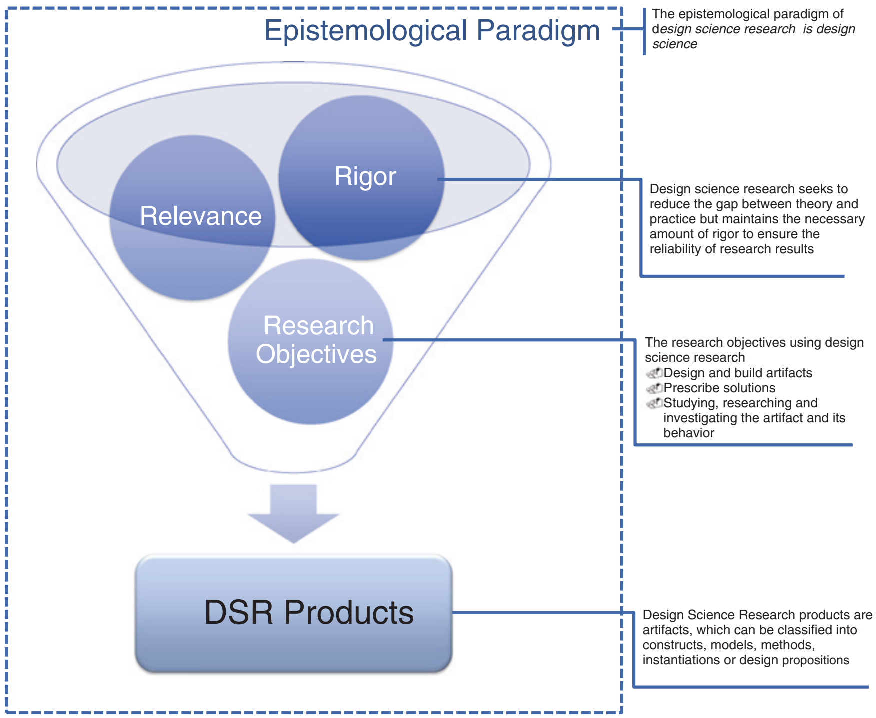

Fig. 4.3 Synthesis of the concepts and foundations of *design science research. Source* The authors

(Cole et al. 2005, p. 3). However, *design science research* should also contribute to the improvement of theories, despite this pragmatic bias (Cole et al. 2005; Gregor and Jones 2007; Walls et al. 1992). Figure 4.3 provides an overview of the key concepts and foundations of *design science research* that were presented in this section.

In the next section, several methods that were formalized for the operationalization of *design science* are presented. In this text, these methods are identified as *design science research*.

4.2 Methods Formalized to Operationalize Design Science

This section presents the proposed and formalized methods for conducting research that is based on *design science*. The proposed methods are derived from diverse areas. However, the majority of the proposed methods are derived from the area of information systems.

Note that the proposed methods received different nomenclatures, such as *design science research* (van Aken 2004, 2005; van Aken et al. 2012; Alturki et al. 2011), *design science research methodology* (Peffers et al. 2007), *design*

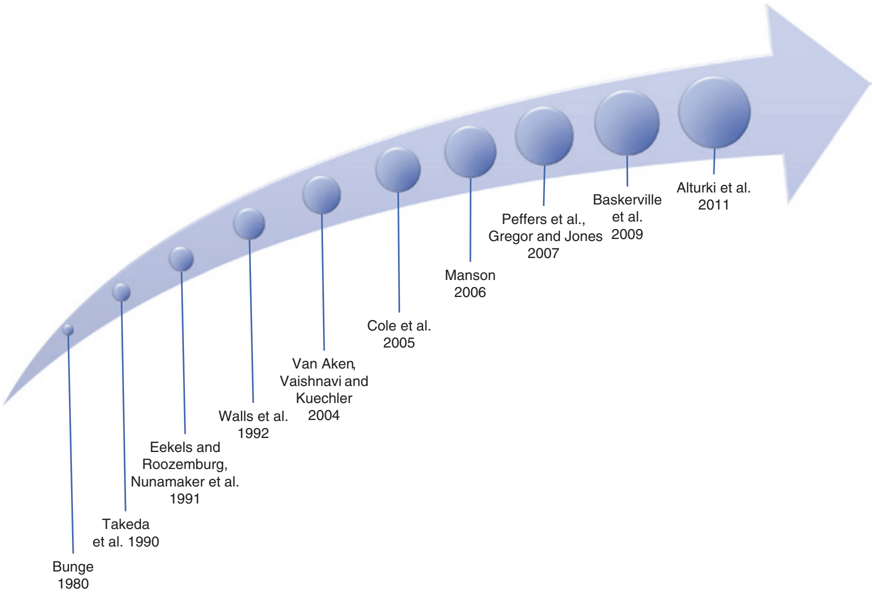

Fig. 4.4 Authors who formalized a method to operationalize *design science*. *Source* The authors

cycle (Eekels and Roozenburg 1991; Takeda et al. 1990; Vaishnavi and Kuechler 2011), and *design research* (Cole et al. 2005; Manson 2006). These differences in nomenclature can also be observed in the definitions of specific concepts and in the manner in which *design science research* is operationalized; these aspects will be recombined and presented in this book.

The term *design science research* will be used in this book to refer to the research method based on *design science*. Figure 4.4 shows the authors who formalized a method to operationalize research based on the paradigm of *design science*.

Bunge (1980) formalized a research method that differed from methods developed by traditional science. Bunge (1980) advocates the need for a method that addresses the development of useful and applicable technologies, that is, a method that not only enables the researcher to learn a certain phenomenon but also helps them to create (Bunge 1980). These ideas significantly resemble the objectives of *design science*. Figure 4.5 shows the method proposed by Bunge (1980).

After a problem is identified, the researcher should seek to *understand the problem* in the first step of the method by For Bunge (1980). This understanding comprises the precise placement of the problem to be studied or the technology to be developed.

Once a problem is understood, the researcher can advance to the second step, in which the objective is to *try to solve the problem*. This attempt to solve the problem should be achieved using the support of the existing knowledge base. Both theoretical and empirical knowledge are considered to be relevant in this step (Bunge 1980).

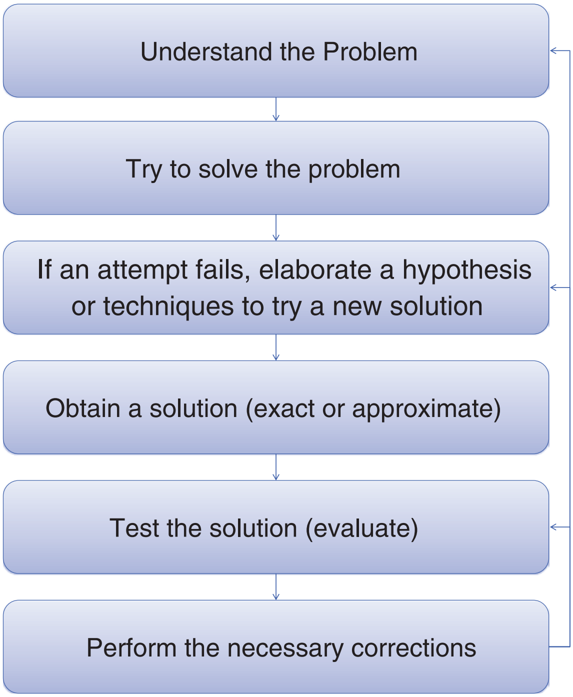

Fig. 4.5 Steps for conducting technological research. *Source* Bunge (1980)

The third step of the method proposed by Bunge (1980) refers to the possibility of creating new hypotheses or techniques to solve the problem when the initial attempt fails. Bunge (1980) suggests the use of hypothetico-deductive systems to solve the problem in this step.

According to Bunge (1980), the fourth step of the method is to *obtain a solution*, which may be exact or approximate, that is, the solution does not have to be an optimal solution if it is a satisfactory solution to the problem (as previously discussed).

Once the researcher has reached a potential solution to the problem, it must be tested (Bunge 1980), that is, the developed solution should be conceptually or materially evaluated to determine whether it is suitable for the intended purpose (Bunge 1980).

Because the technological solution was evaluated, it is possible to determine what improvements must be made for its operation. Thus, the last step of the method proposed by Bunge (1980) is to *perform the necessary corrections*. To perform these corrections, the researcher should revisit the previous steps to seek opportunities for improvement.

Takeda et al. (1990) formalized a method for conducting research based on *design science* (although not explained in this manner). The objective of the developed method, which is referred to as the *design cycle*, is to construct a computational model that can support the development of intelligent *computer-aided design* (CAD) systems (Takeda et al. 1990). This method, which consists of five steps, is represented in Fig. 4.6.

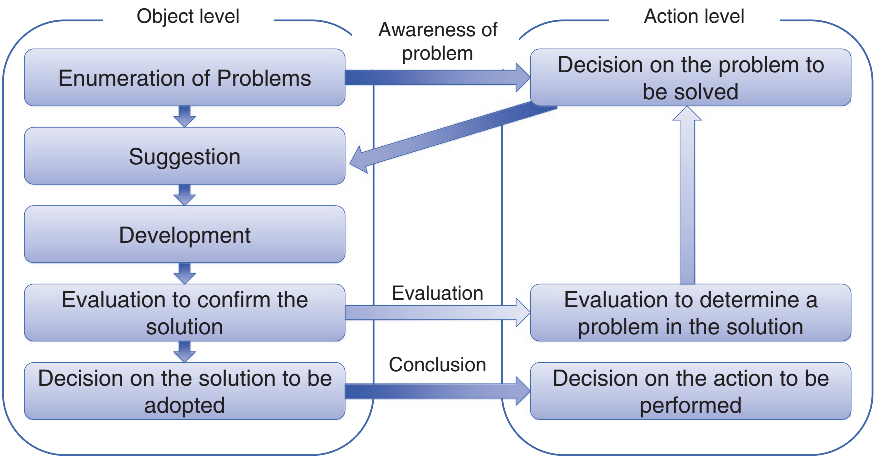

Fig. 4.6 *Design cycle* by Takeda et al. (1990). *Source* Takeda et al. (1990)

The first step of the method is the *awareness of the problem*, in which the objective is to "pick up a problem by comparing the object under consideration with the specifications" (Takeda et al. 1990, p. 43). In the second step, which is referred to as the *suggestion*, concepts are proposed to help researchers to solve the problem (Takeda et al. 1990).

The third step is the *development*. According to Takeda et al. (1990), the researcher develops potential solutions to the problem, for which he/she employs key concepts that are defined in the previous step. The fourth step is the *evaluation,* in which the developed artifact is critically analyzed. In this step, different tools can be used to help the researcher, such as simulation and cost analysis (Takeda et al. 1990).

The last step is the *conclusion*. In this step, the researcher defines which of the developments yielded optimal results for the problem (Takeda et al. 1990). Takeda et al. (1990) emphasize that a single problem is solved in each cycle. However, during the application of the method, new problems may arise and a new cycle must be applied to study these problems.

Other authors (Eekels and Roozenburg 1991; Nunamaker et al. 1991) have formalized methods to conduct research based on *design science*. Eekels and Roozenburg (1991) compared a traditional research method and a proposed method for the development of research in the field of engineering. According to Eekels and Roozenburg (1991), engineering research can be developed through a method referred to as the *design cycle* (shown in Fig. 4.7), which is the same terminology used by Takeda et al. in 1990; however, the steps and characteristics of the cycle differ.

The research method formalized by Eekels and Roozenburg (1991) begins with the definition of the *problem*. The problem is defined as the "discrepancy between the facts and our set of value preferences concerning these facts" (Eekels and Roozenburg 1991, p. 200). The objective is to transform the system to achieve the desired results. The second step of the cycle is the *analysis.* In this step, the researcher analyzes the current situation and potential solutions to the problem and always strives to improve

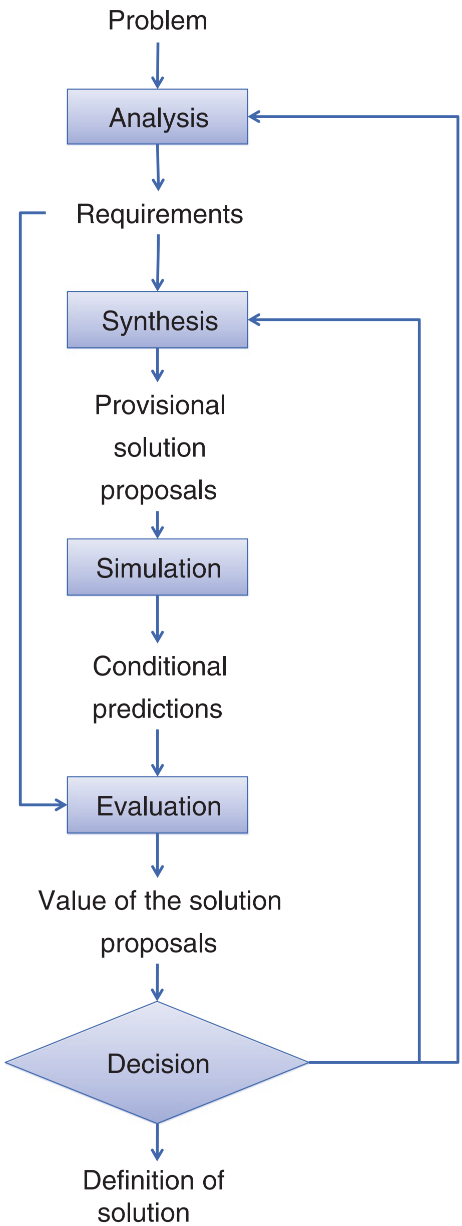

Fig. 4.7 *Design cycle* by Eekels and Roozenburg (1991). *Source* Eekels and Roozenburg (1991, p. 199)

the current situation (Eekels and Roozenburg 1991). To support the reasoning process, the researcher can employ items, such as books and journals.

The third step of the cycle is the *synthesis*. In this step, the researcher considers the entire situation that he/she is attempting to solve or improve. All aspects of the problem should be understood by the researcher (Eekels and Roozenburg 1991).

By the end of the synthesis, the researcher should develop a preliminary proposal of the product/process for solving the problem. The fourth step of the cycle refers to *simulation*. Here, the initially proposed solutions are tested. The model is constructed and subsequently tested; the researcher can use the model to predict hypotheses (Eekels and Roozenburg 1991).

The fifth step of the cycle is the *evaluation*. In this step, the researcher verifies whether the results obtained in the simulation satisfy the previously defined research requirements (Eekels and Roozenburg 1991). In the last step, in which a *decision* is made, the researcher defines the best solution for the problem. Based on this decision, the actual performance of the solution can be analyzed (Eekels and Roozenburg 1991).

In 1991, Nunamaker et al. (1991) published a text that was instrumental in introducing *design science* in the area of information systems (Peffers et al. 2007). Nunamaker et al. (1991) advocate the integration of the processes of traditional research and systems development. They propose a multimethodological approach, which includes the formation of theories in the development of systems through experimentation or observation (Peffers et al. 2007).

According to Nunamaker et al. (1991), the research results are used to expand the existing knowledge base. Figure 4.8 shows the system development research process proposed by Nunamaker et al. (1991).

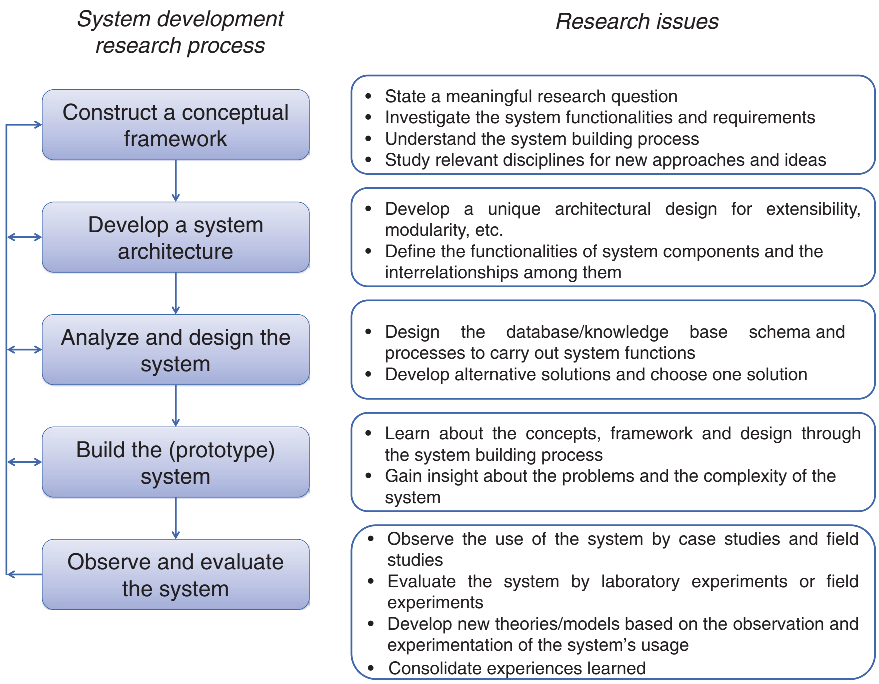

Fig. 4.8 System development research process. *Source* Nunamaker et al. (1991, p. 98)

The first step of the system development research process proposed by Nunamaker et al. (1991) is to *construct a conceptual framework*, which can support the researcher in justifying the research. The research question is also formalized in this step. This question should have significant relevance to the area in which the study is being conducted. During this stage, the researcher should examine disciplines that are relevant to his/her research, which may contribute to the emergence of new ideas and approaches to address the proposed research question (Nunamaker et al. 1991).

The second step—*develop a system architecture*—helps the researcher to present the components of the artifact, its functionalities, and the interaction among its components (Nunamaker et al. 1991). In this step, the researcher must also define the system requirements to enable the performance of the system to be tested in the evaluation stage (Nunamaker et al. 1991).

The third step of this research process is *analyze and design the system*, which addresses the understanding of what is being studied and the application of scientific knowledge to create alternative solutions to the problem (Nunamaker et al. 1991). Once potential solutions are defined, Nunamaker et al. (1991) argue that the researcher should select one of the proposed solutions to ensure continuity of research.

In the fourth step of the process—*build the (prototype) system*—the researcher tests the constructed artifact to determine how it will behave in a real or near-real situation (Nunamaker et al. 1991). According to Nunamaker et al. (1991), this construction is essential to assess the feasibility, functionalities, and problems of the project. Based on the observed results, the study may be modified to improve the system and ensure that the research question is properly answered.

In the last step of the process proposed by Nunamaker et al. (1991)—*observe and evaluate the system*—the performance and applicability of the system, which are relative to the conceptual framework and the predetermined requirements in the first step of the process, are assessed. At the end of this step, the researcher may propose new theories and models that should be generalized to support future researchers (Nunamaker et al. 1991).

In 1992, another method was proposed that is also based on the paradigm of *design science*. Walls et al. (1992) published a paper advocating the use of *design science* concepts for research in areas such as engineering, architecture, arts, and information systems. The paper primarily discusses the possibility of forming theories from design concepts. For Walls et al. (1992, p. 41), the goal of a theory based on the design concepts is "to prescribe both the properties an artifact should have if it is to achieve certain goals and the method(s) of artifact construction." The method proposed by Walls et al. (1992) for constructing theories is represented in Fig. 4.9.

Walls et al. (1992, p. 42) define design as a product and a process. As a product, design is "a plan of something to be done or produced,", whereas as a process, design is a way to conceive a particular artifact that satisfies all requirements (Walls et al. 1992). Thus, design theory should consider two elements: product and process.

In the first step, the process of constructing *design science*-based theories begins with the definition of a set of *kernel theories*, which are theories that are

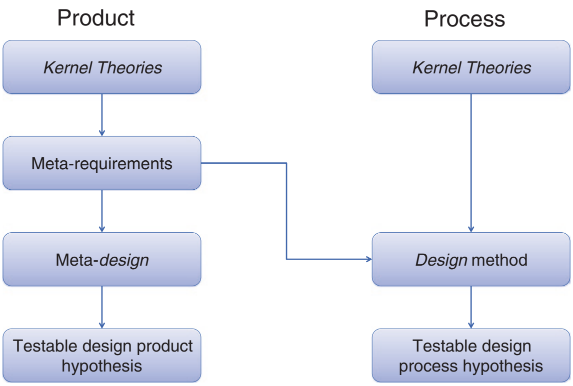

Fig. 4.9 Components for constructing design-based theories in the area of information systems. *Source* Walls et al. (1992, p. 44)

well established and recognized by the natural and social sciences and that will influence the requirements to be defined in subsequent steps (Walls et al. 1992).

The second step of the method includes a set of *meta-requirements* (Walls et al. 1992). Meta-requirements describe the class of problems addressed in the research (Walls et al. 1992). The third step—the *meta-design*—involves the construction of *design science*-based *theories*, which describes possible artifacts or classes of artifacts that satisfy the meta-requirements of the previous step (Walls et al. 1992).

The fourth step refers to the *testable hypothesis*. Testable hypotheses are elements that can be tested to determine if what was defined in the *meta-design* stage satisfies the set of meta-requirements that were defined in the second step of the research to construct theories (Walls et al. 1992).

When the research is developed from the process viewpoint, the first component to be defined is a set of *kernel theories*, that is, well-established theories in the natural and social sciences, which may exert some influence in the design process and should be considered by the researcher (Walls et al. 1992).

In the second step, which is referred to as the *design method*, the researcher describes the procedures that will be employed to construct the artifact. The last step of the method proposed by Walls et al. (1992) relates to the hypotheses that can be tested to determine whether the results of the design method, that is, an artifact, is consistent with the expectations (Walls et al. 1992), that is, if the artifact will have the conditions to satisfy the expectations that were previously defined by the researcher.

Concerned with research in the area of information systems, Vaishnavi and Kuechler (2011) published a paper in 2004 about their method based on design science research, which is referred to as the *design cycle*. The proposed method is an improvement of the design cycle proposed by Takeda et al. (1990), as shown in Fig. 4.10.

The first step of the method proposed by Vaishnavi and Kuechler (2011) relates to the *awareness of the problem*. At this stage, the researchers must identify and understand the problem and how they should define the performance required for the system under consideration.

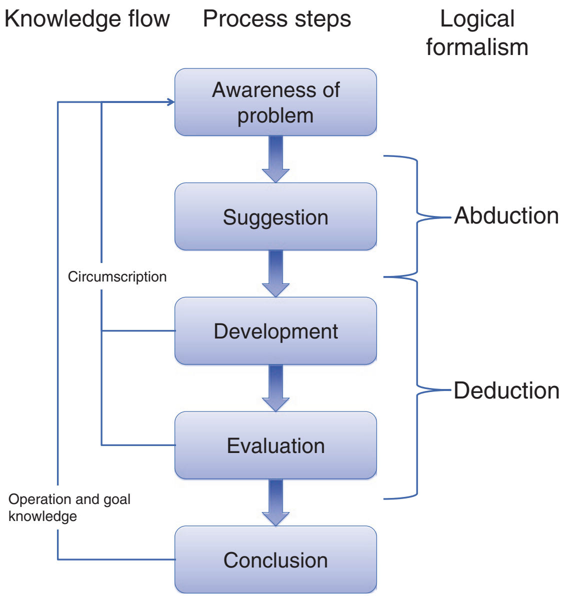

Fig. 4.10 *Design cycle* by Vaishnavi and Kuechler (2011). *Source* Vaishnavi and Kuechler (2011)

In the second step, the researcher must *suggest* possible solutions to the problem. This step is performed using the abductive scientific method described in the previous chapters because the researcher must use creativity and their prior knowledge to propose solutions that can be used to improve the current situation (Vaishnavi and Kuechler 2011).

The third step of the method is the *development* of one of the artifacts that was proposed by the researcher in the previous step to solve the problem. These developments that have proved suitable to solve the problem are subsequently *evaluated* (fourth step). However, if during development or evaluation, the artifact did not adhere to the research requirements, the researcher can return to the awareness step to better understand the problem and continue the research (Vaishnavi and Kuechler 2011).

This learning generated during the execution of the method generates new knowledge not only for researchers but also for persons who have access to their research. In Fig. 4.10, interactions between the steps, which are referred to as *circumscription,* are represented by arrows. According to Vaishnavi and Kuechler (2011), the circumscription process is essential for a better understanding of the research being conducted because it enables people other than the researchers involved to understand and learn from the process of artifact construction. It also enables the researcher to learn from unexpected situations and problems, which is a counterpoint of its results with the existing theory (Vaishnavi and Kuechler 2011).

The final step of this method is the *conclusion*, in which the researcher presents the results (Vaishnavi and Kuechler 2011). According to the findings, the researcher eventually realizes that the awareness of the problem was incomplete or insufficient and that, thus, the development of an artifact is unsuccessful.

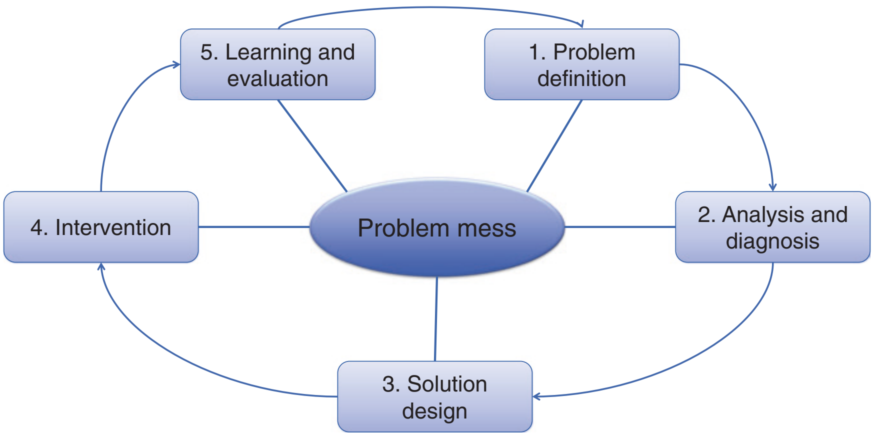

Fig. 4.11 Problem-solving cycle. *Source* van Aken et al. (2012, p. 12)

Therefore, the design cycle can restart and may even generate contributions regarding gaps in the theory, the lack of which may result in an inadequate artifact for solving the problem at the time of awareness.

In the 2000s, van Aken (2004, 2005) and van Aken et al. (2012) published papers and a book on this topic. For van Aken (2004, 2005), van Aken et al. (2012), *design science* can reduce the existing gap between academic research and the requirements of organizations.

The texts developed by van Aken (2004, 2005) and van Aken et al. (2012) are addressed to focus the research on the solution of problems in organizations. Figure 4.11 shows a problem-solving cycle based on the fundamentals of *design science*, which was proposed by van Aken et al. (2012, p. 12). These solutions result in recommendations, which must be generalized to a certain class of problems. This generalization will enable the creation of knowledge in a particular situation to be subsequently applied to similar situations experienced by various organizations (van Aken 2004, 2005; van Aken et al. 2012).

Based on the identification of a *problem,* it is essential for this problem to be properly understood and defined. Once the problem is understood, the next step in the cycle proposed by van Aken et al. (2012) is the *analysis and diagnosis of the problem*, in which the problem, the environment and the context in which it occurs are analyzed to understand the causes of the problem.

Once the main causes are identified, it is possible to begin to *design a solution* to the problem; how this solution can be implemented should also be considered by the researcher (van Aken et al. 2012). In the next step of *intervention*, the proposed solution is implemented in the study organization. According to van Aken et al. (2012), the *evaluation* step must be performed, in which the changes effected by the implementation of the solution will be assessed. Eventually, this evaluation and the *learning* generated by the problem-solving cycle may cause researchers to recognize new problems that require analysis; thus, a new cycle begins (van Aken et al. 2012).

van Aken et al. (2012) also differentiate three processes for knowledge generation: theory development, theory testing, and reflective design. In theory development, the research method serves as the case study (van Aken et al. 2012). The process of theory development begins with the observation of a phenomenon that has not been adequately explored in the academic literature (van Aken et al. 2012). According to van Aken et al. (2012), researchers observe the phenomenon, develop explanations, and compare these explanations with existing theories. Propositions that modify the existing theory are formulated to generate new knowledge (van Aken et al. 2012).

Once the theory is developed, another knowledge generation process may begin: theory testing. This process assists in the conclusion and validation of the results obtained during theory development (van Aken et al. 2012). The first step of the process is to identify explanations in the academic literature that are not conclusive about a specific phenomenon (van Aken et al. 2012). van Aken et al. (2012) suggest that the researcher can generate a conceptual model and hypotheses that can be tested. Hypotheses should be examined and the researcher can deduce conclusions about the phenomenon to confirm the previously developed theory (van Aken et al. 2012).

The third process of knowledge generation is significantly related to the concepts of *design science* and this study. According to van Aken et al. (2012), the *reflective design* is based on the problem-solving cycle (see Fig. 4.12). Note that the goal of the reflective design is not problem solving in a single and particular context but generic solutions that can be applied in various contexts (van Aken et al. 2012).

Once the problem is defined, the researcher can apply the problem-solving cycle. However, in the case of reflective design, which was proposed by van Aken et al. (2012), the researcher should reflect to analyze the problem and the proposed solution in an aggregated form after application of the cycle to generalize the knowledge gained in the research. The researcher must disregard particular details of the company and define general requirements—design propositions—for a given class of problems.

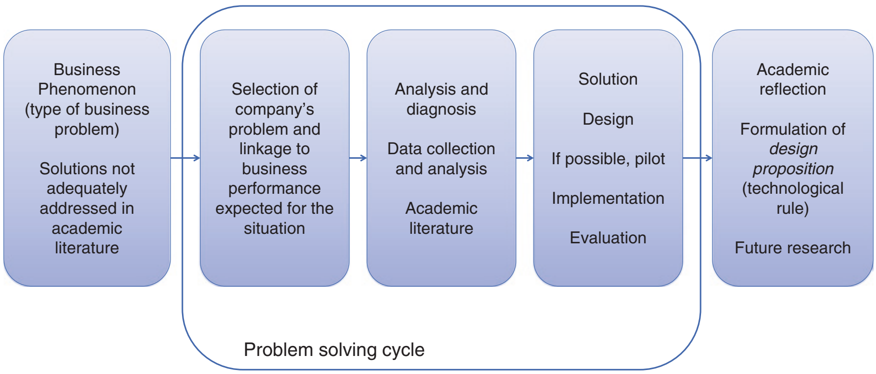

Fig. 4.12 Reflective design. *Source* van Aken et al. (2012)

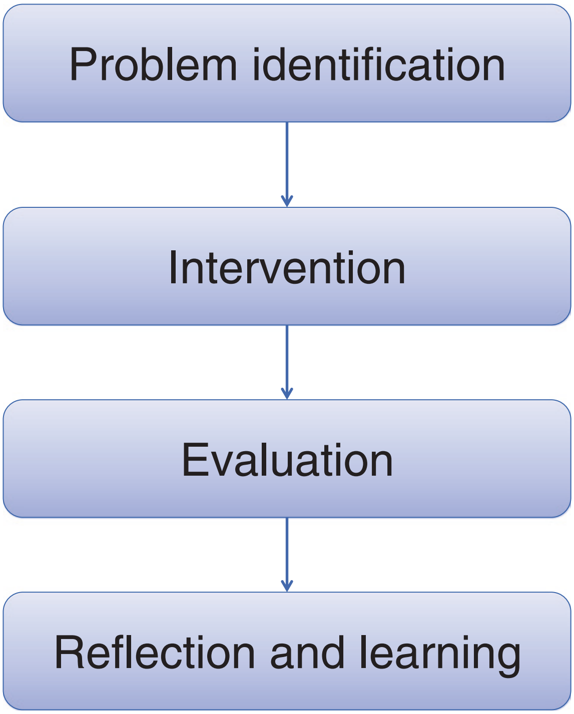

Fig. 4.13 Synthesized research approach by Cole et al. (2005). *Source* Cole et al. (2005)

Cole et al. (2005) developed a method for conducting research based on *design science*. They focus on research conducted in the area of information systems, in which methods should be implemented that may contribute to academic researchers and to professionals in organizations.

The text suggests combining the *design science* approach with a consolidated research method—action research (Cole et al. 2005). The authors propose a research method that is a synthesis of action research and the central concepts of *design science*. The integration of these research methods is interesting, especially regarding the design or construction of an artifact in a real context/environment. This type of artifact, which is referred to as instantiation, may also require the interaction between the researcher and the members of an organization in which the artifact will be constructed. Therefore, the use of elements of action research can contribute to the success of the research and intervention in the organization. Figure 4.13 shows the steps for conducting research as proposed by Cole et al. (2005).

The first step of the method—*problem identification*—concerns the identification of the problem and considers two core aspects: understanding the problem and understanding the interests of persons involved in solving this problem, considering the practical relevance of the problem for all involved (Cole et al. 2005). The second step—*intervention*—corresponds to the construction of an artifact to solve the problem and intervention to provide change in the organization (Cole et al. 2005).

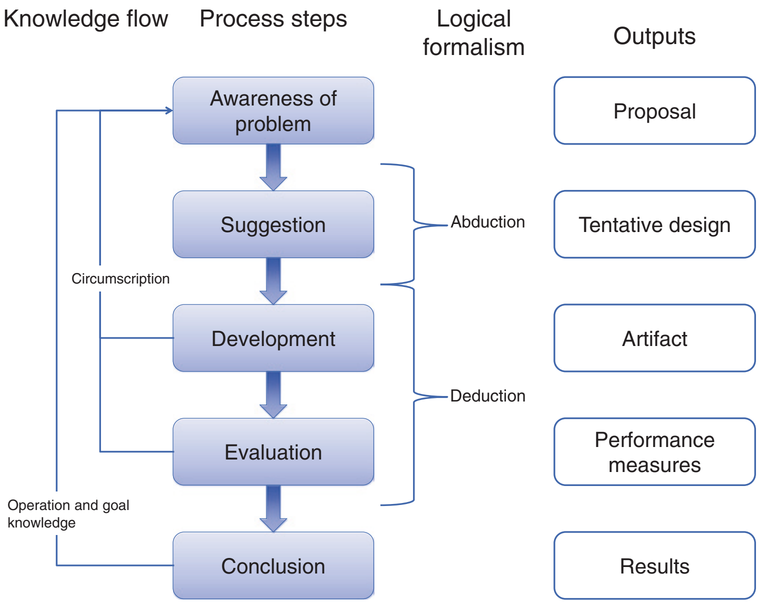

Fig. 4.14 Outputs of *design science research. Source* Manson (2006)

The third step concerns the *evaluation* of both the artifact that was constructed and the change observed in the organization (Cole et al. 2005). In this step, the researcher determines whether the artifact and the intervention satisfy the objectives. According to Cole et al. (2005), the last step—*reflection and learning*—ensures that the research serves as a basis for the generation of knowledge in practical and theoretical fields. The contributions of these studies are consistent with the expectations of the research, in which the objective is to reduce the existing gap between theory and practice.

Based on the method originally proposed by Vaishnavi and Kuechler (2011), Manson (2006) explains the outputs that can be generated from the completion of each step of *design science research*. Figure 4.14 shows the method proposed by Vaishnavi and Kuechler (2011) and the outputs of each step in the process proposed by Manson (2006).

According to Manson (2006), once the *awareness of the problem* stage is completed, the researcher can submit a formal or informal *proposal* to begin other research activities. The proposal should consist of evidence of the problem and characterization of the external environment and their points of interaction with the artifact to be developed by defining metrics and criteria for acceptance of the artifact, as well as clarification of the parties involved with the artifact to be developed and the classes of problems to which the artifact may be related (Manson 2006).

At the end of the next step—the *suggestion*—the researcher will obtain as an output one or more *Tentative Designs*, which aim to solve the previously defined problem (Manson 2006). The researcher should explain the assumptions that will be considered for the construction of the artifact, record all tentative designs (including excluded designs) and record their reasons for selecting a tentative design (Manson 2006).

In the *development* step, one or more *artifacts* comprise the outputs. The researcher should justify the choice of tools that were used for the development of the artifact, its components, and their causal relationships that generated the desired effect for the artifact to accomplish its goals. At the end of this step, validation of the artifact should be explained (Manson 2006).

Once developed, the artifacts will be tested in the *evaluation* step. Once evaluated, the *performance measures* for the artifacts can be developed to compare them with the requirements that were defined in the steps preceding the development (Manson 2006). At this stage, the researcher should detail the mechanisms for evaluating the artifact and show the results (Manson 2006). According to Manson (2006), the researcher should indicate the involved parties, especially with regard to qualitative evaluations (to prevent bias). The researcher should also emphasize successful planning and recommended adjustments (Manson 2006)

In the last step of the method—the *conclusion*—the researcher must analyze, consolidate, and properly record the *results* of their research (Manson 2006). At this stage, the researcher must synthesize the learning for all phases of the project and also justify the contribution of their work to the class of problems, which were identified in the first phase of the process (Manson 2006).

Peffers et al. (2007) consolidate a method for conducting research under the *design science* paradigm (depicted in Fig. 4.15). To construct this method, the authors reviewed texts by various authors who also prescribed solutions for problem

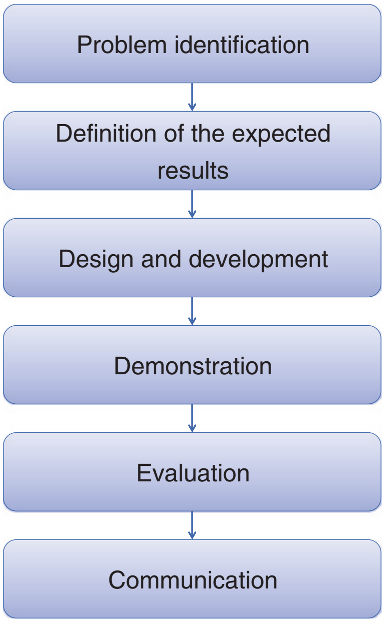

Fig. 4.15 Research method proposed by Peffers et al. (2007). *Source* Peffers et al. (2007)

solving and artifact construction (Cole et al. 2005; Eekels and Roozenburg 1991; Hevner et al. 2004; Nunamaker et al. 1991; Takeda et al. 1990; Walls et al. 1992).

According to Peffers et al. (2007), the first activity of the method is *problem identification* and the definition of the points that motivate the research. At this stage, the researcher should justify the importance of the research, considering its relevance, the importance of the problem, and the applicability of the proposed solution (Peffers et al. 2007).

The second step of the method concerns the *definition of expected results* for the problem. Peffers et al. (2007) suggest that the expected objectives from solving the problem can be both quantitative and qualitative. The third research activity is referred to as design and development. In this stage, the artifact that will help solve the problem is developed. In the *design and development* step, the desired functionalities for the artifact, its proposed architecture, and its development should be defined. The researcher should use existing theoretical knowledge to propose artifacts that support problem solving (Peffers et al. 2007).

The fourth step of the method proposed by Peffers et al. (2007) refers to the *demonstration*, that is, use of the artifact to solve the problem. This step can be performed through experimentation and simulation (Peffers et al. 2007). The fifth research activity refers to *evaluation*. The researcher should observe and measure the behavior of the artifact for solving the problem (Peffers et al. 2007). In the *evaluation*, the researcher should compare the artifact performance results with the requirements for solving of the problem (second step of the method). If the outcome does not satisfy the expectations, the researcher can return to the *design and development* step to develop a new artifact (Peffers et al. 2007).

The *communication* step is presented by Peffers et al. (2007). This step enables the researcher to communicate the problem and its relevance. In this stage, the rigor with which the research was conducted should be presented, as well as the effectiveness of the solution to the problem. To perform the communication, Peffers et al. (2007) suggest that researchers employ academic literature.

A particularity of the method proposed by Peffers et al. (2007) is that the research does not need to begin in step 1 and be completed in step 6. Peffers et al. (2007) indicate that the research method can be applied differently according to the type of problem and the research objective and its starting point can be modified according to the goals of the researcher (Peffers et al. 2007).

Due to the development of theories based on the concepts of *design science*, Gregor and Jones (2007) expanded the work of Walls et al. (1992) and proposed a method for theory building. The method, which consisted of eight components, primarily aims to develop theories from studies conducted in the area of information systems. Figure 4.16 shows the method proposed by Gregor and Jones (2007).

The first step of the method proposed by Gregor and Jones (2007) refers to the definition of the *purpose and scope* of the research. That is, in this stage, the researcher should clarify the type of system to which the theory can be applied and its requirements. However, these requirements must be conjectured in a macro manner, that is, by focusing not only on the application of the theory to support the solution of one problem or the study of a system but also on a specific class of

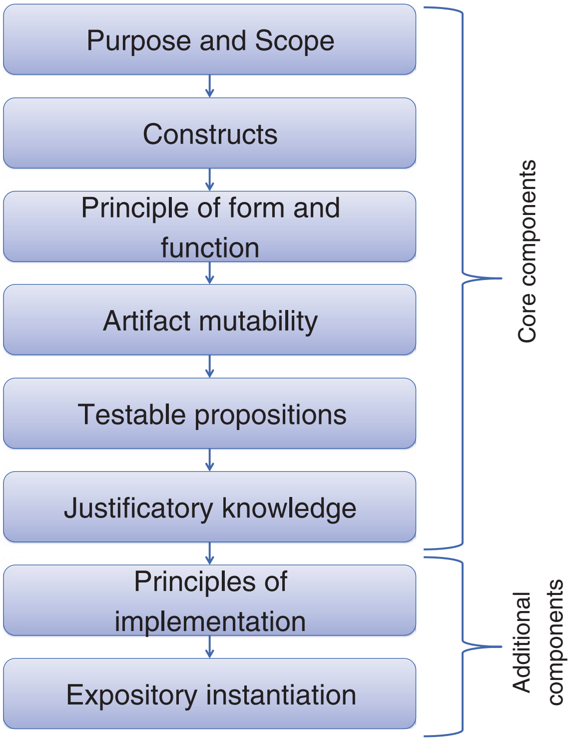

Fig. 4.16 Method proposed by Gregor and Jones (2007). *Source* Adaptation from Gregor and Jones (2007, p. 322)

problems. Thus, the type of system to which the theory can be applied and its limitations and scopes should also be considered in this step (Gregor and Jones 2007).

In the second stage, *constructs* are determined, which correspond to the representation of components of interest for the theory (Gregor and Jones 2007). The constructs should be clear and concise and are usually represented by words and diagrams (Gregor and Jones 2007). The third step concerns the *principles of form and function*; in this stage, the characteristics of the system architecture being developed or improved, i.e., the internal environment of the artifact, are defined (Gregor and Jones 2007). This step refers to either a product or a method.

The fourth component of the method proposed by Gregor and Jones (2007) is referred to as *artifact mutability*, that is, changes in the state of the artifact that can be anticipated by theory or “what degree of artifact change is encompassed by the theory” (Gregor and Jones 2007, p. 322). In this step, the researcher should reflect on the behavioral dynamics of the artifact from its construction, use, and disposal. This reflection is considerably beneficial when a theory is constructed based on *design science* because it facilitates consideration of the researcher regarding the different adaptations that artifacts must undergo according to the context in which they will be applied.

The fifth step of the method—*testable propositions*—enables the theory to be tested and several hypotheses aimed at visualizing the behavior of the system to be constructed in different contexts (Gregor and Jones 2007). Gregor and Jones (2007) argue that the generalization of these propositions should be a requirement for the research to generate a robust theory.

The sixth stage regarding the basic components of the method proposed by Gregor and Jones (2007) is referred to as *justificatory knowledge*. The knowledge generated by the research will be more robust if the existing theory from the natural or social sciences, which were named *kernel theories* by Walls et al. (1992), or *design science* are considered (Gregor and Jones 2007). Gregor and Jones (2007) emphasize that by considering existing knowledge, regardless of the type of science with which it was generated, it is possible to explain the importance of constructing an artifact and why it works. This explanation is also important for communicating the research that was conducted.

A second phase of the method proposed by Gregor and Jones (2007) comprises two steps, *principles of implementation*, which relates to the approach used to implement the artifact and evaluate the developed theory (Gregor and Jones 2007) and *expository instantiation*, which concerns the application/use of the artifact in a real context. The instantiation in the context of constructing *design science*-based theories helps to identify potential problems in the developed theory (Gregor and Jones 2007). The instantiation favors the visualization of exposed theoretical concepts and facilitates the understanding of these concepts and the translation of their value (Gregor and Jones 2007).

Baskerville et al. (2009) proposed a method named *soft design science research*, which encompasses concepts from the following approaches: *design science research* and *soft system methodology*. This new method is suitable for conducting research to solve problems and improve conditions in organizations, especially considering the social aspects that are inserted into the core activities of *design science research*: design, develop and evaluate (Baskerville et al. 2009).

As shown in Fig. 4.17, Baskerville et al. (2009) make a distinction between two "worlds" for conducting research based on the *soft design science research* method: the "real world" and a more abstract world that is referred to as "design thinking." The "real world" comprises, for example, the construction and evaluation of the artifact that will be implemented to solve the problem. In the more abstract world of thinking, activities are based on the concepts of *design science* due to the search for a solution and evaluation of the proposed solution (Baskerville et al. 2009).

As shown in Fig. 4.17, in the first step of the method proposed by Baskerville et al. (2009), the researcher should identify and outline a *specific problem*. In the second step, the problem must be detailed in the form of a set of requirements. These two steps of the method occur in the real world according to Baskerville et al. (2009). Design thinking occurs in the third step according to Baskerville et al. (2009), in which the researcher generalizes the specific problem into a *general problem*. This generalization identifies a class of problems that guide the research.

Subsequently, the *general problem requirements* must be defined, that is, in the same manner in which a class of problems was defined, a class of solutions to the general problem should be developed. This step can be performed using techniques known as systemic thinking; the result is a series of general requirements that will guide the researcher in subsequent phases of the method (Baskerville et al. 2009).

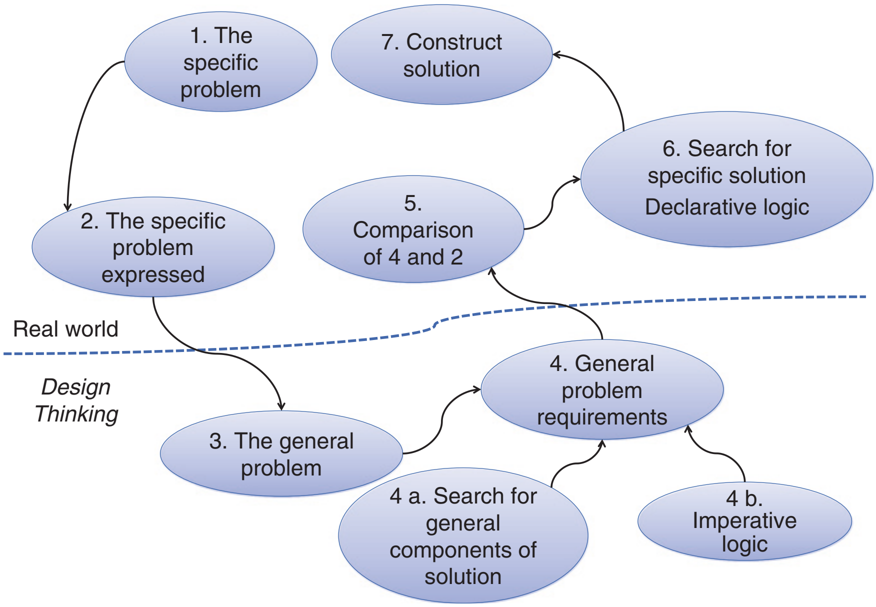

Fig. 4.17 Method proposed by Baskerville et al. (2009). *Source* Baskerville et al. (2009)

In the fifth step of the method, a *comparison* between what was established in step 2 and what was established in step 4 should be performed. That is, the requirements of the specific problem should be compared with the defined general requirements (Baskerville et al. 2009). This activity is required for the specific problem (Step 2) to be revised in accordance with the general requirements (Step 4) (Baskerville et al. 2009).

In the sixth step, Baskerville et al. (2009) indicate that a *search for a specific solution* should be performed for the problem. To perform this search, the researcher should consider the general requirements that were defined in step 4. The final step is to *construct a solution* and implement the solution in the study context (Baskerville et al. 2009).

After implementing the solution, the problem should be evaluated to determine whether it was solved or if the system showed some change after the intervention (Baskerville et al. 2009). Baskerville et al. (2009) emphasize that learning should be explicitly defined and a new cycle should be initiated.

Alturki et al. (2011) proposed a design science-based research method. The proposed method derives from the synthesis of ideas formalized by several authors, particularly in the area of information systems (van Aken 2004; Baskerville et al. 2009; Cole et al. 2005; Gregor and Jones 2007; Hevner et al. 2004; March and Smith 1995; March and Storey 2008; Nunamaker et al. 1991; Peffers et al. 2007; Vaishnavi and Kuechler 2011; Venable 2006; Walls et al. 1992). Figure 4.18 shows the method proposed by Alturki et al. (2011), which is referred to as the *design science research cycle*.

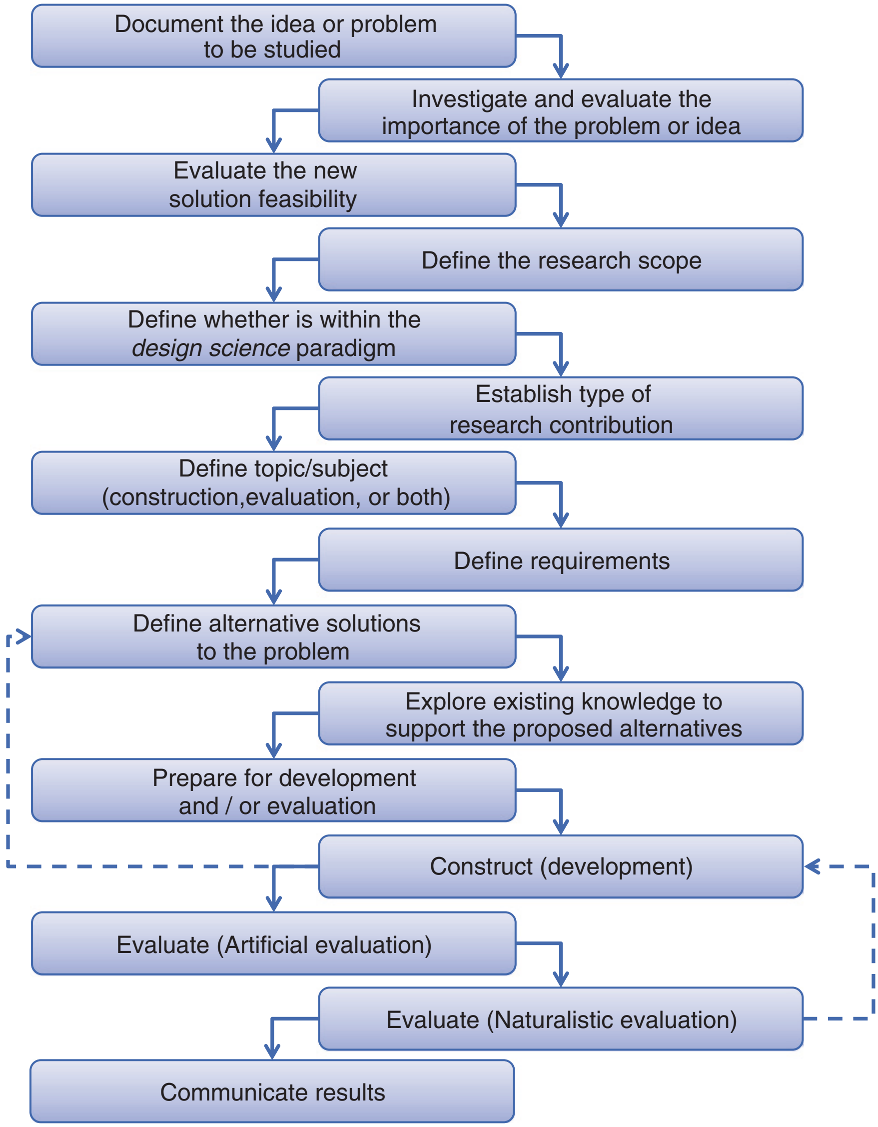

Fig. 4.18 *Design science research cycle* by Alturki et al. (2011). *Source* Based on Alturki et al. (2011)

The starting point for the research that employs the method proposed by Alturki et al. (2011) is the *documentation of the idea or problem*. This idea derives from the needs of professionals within organizations and researchers who perceive gaps in existing knowledge and wish to propose new solutions to specific problems (Alturki et al. 2011).

The second step of the method aims to *investigate and evaluate the importance of the problem or idea*. The problem is considered to be an important research topic if it has not been solved in a certain class of problems and if the research will contribute to the respective field of knowledge (Alturki et al. 2011). This step ensures that research based on *design science* satisfies its purpose: the production of new knowledge (Alturki et al. 2011).

To operationalize these activities and justify and ensure the relevance of the study, the researcher can employ existing knowledge about the subject. The researcher may also collect data through interviews, case studies, experiments, and surveys (Alturki et al. 2011).

The third step of the method according to Alturki et al. (2011), corresponds to the *evaluation of solution feasibility*. That is, simply solving the problem is not sufficient, and the proposed solution must be appropriate for the context of the organization in which the research is being conducted and must correspond with the human resources, financial resources, and values of the organization (Alturki et al. 2011).

Once the feasibility of the solution is confirmed, the fourth step of the method commences, i.e., *define the research scope.* In this step, the objectives, limitations, and limitations of the research are defined, which in the case of *design science research,* are dynamic and can be revisited throughout the development of the study (Alturki et al. 2011).

After defining the scope and considering the research objectives, it is necessary to determine if the scope is within the *design science paradigm*. If the research corresponds with this paradigm, then the remaining steps of the method can be completed; otherwise, alternate methods should be used to conduct the study (Alturki et al. 2011).

The sixth step of the method refers to the *definition of the type of research contribution* that is expected. Two types of contributions are described by Alturki et al. (2011): (i) create a solution for a specific and relevant class of problems using a strict process of artifact construction and evaluation and (ii) reflect on the research process to create new standards that ensure rigorous investigations (Alturki et al. 2011).

The seventh step—*definition of the research topic/subject*—defines the study as artifact construction and/or evaluation. This definition is important because different specialties and resources may be required according to the research objectives (Alturki et al. 2011).

The eighth step refers to the *definition of requirements*. Here, the tools, experience, and skills required to conduct the study are defined (Alturki et al. 2011). The night step generates the proposed *alternative solutions* to the problem. These proposed solutions are aimed at improving the current situation, transforming it into a desirable situation, and solving the problem by considering the previously defined requirements and the available resources to achieve the goals (Alturki et al. 2011).

The tenth step of the method proposed by Alturki et al. (2011) includes the *exploration of existing knowledge* that can support the proposed solutions. This knowledge derives from the natural and social sciences (*kernel theories* cited by Walls et al. (1992)). Identification of these existing theories will support the solutions proposed in the previous step; it is a key activity because the artifact being constructed or evaluated by the *design science research* method is subject to the natural and social sciences, that is, it cannot violate the laws advocated by traditional sciences. Knowledge of existing theories and its gaps helps the researcher to exert greater assertiveness regarding the choice of a solution to the problem and favors the identification of new topics that may lead to future research (Alturki et al. 2011).

The eleventh step aims to *prepare for the development and/or evaluation* of the artifact. Here, the methods for constructing and evaluating the artifact are defined. The metrics that will be used to evaluate the success of the development and the artifact performance are also to be defined (Alturki et al. 2011).

Subsequently, the *development* of a solution to the problem or the construction of a new artifact is performed. In addition to the physical construction of the artifact, its functionality, architecture, and general features must also be defined in this step (Alturki et al. 2011).

Once the artifact is developed, it must be evaluated. If rigorously conducted, the *evaluation* ensures greater recognition of the research by academia (Alturki et al. 2011). Evaluation in *design science research* does not aim to expose "why" or "how" the artifact operates but "how well" this artifact performs its functions (Alturki et al. 2011).

The evaluation step proposed by Alturki et al. (2011) is divided into two stages, *artificial evaluation* and *naturalistic evaluation*. The first stage refers to internal testing that the artifact should undergo, for example, in a laboratory context using simulation or experiments. If the artifact or the proposed solution does not perform well in this first evaluation, alternative solutions should be defined (Alturki et al. 2011). However, if the internal evaluation yields acceptable results, natural evaluation should be performed. This evaluation occurs within a real context, e.g., within an organization. It is usually a more expensive and complex evaluation because it involves people, processes, and a series of variables that are difficult to control (Alturki et al. 2011).

After these steps, the results obtained should be *communicated*. This communication should preferably reach both the academic community and the professionals within organizations. The disclosure of the results, the limitations, and newly generated knowledge will assist professionals in the implementation of the proposed solutions in their particular contexts, most likely with adaptations (Alturki et al. 2011). Communication also enables researchers to become familiar with the theoretical and methodological contributions of the research (Alturki et al. 2011).

Each author proposes different methods of conducting research based on *design science*, however, some similarities have been identified. Table 4.1 summarizes the main elements of the proposed research methods described in this chapter.

As shown in Table 4.1, the authors cited in this chapter consider similar elements when proposing a method for conducting research based on *design science*. For example, all authors suggest the need for a proper definition of the problem as a step of artifact development (van Aken et al. 2012; Alturki et al. 2011; Baskerville et al. 2009; Bunge 1980; Cole et al. 2005; Eekels and Roozenburg 1991; Gregor and Jones 2007; Nunamaker et al. 1991; Peffers et al. 2007; Takeda et al. 1990; Vaishnavi and Kuechler 2011; Walls et al. 1992).

Table 4.1 Main elements of *design science research*

Authors	Main steps of the method							
	Problem definition	Literature review or search for existing theories	Suggestions for possible solutions	Development	Evaluation	Decision about the best solution	Reflection and learning	Communication of results
Bunge	X		X	X	X			
Takeda et al.	X		X	X	X	X		
Eekels and Roozemburg	X		X	X	X	X		
Nunamaker et al.	X		X	X	X			
Walls et al.	X	X	X	X				
van Aken et al.	X		X	X	X		X	
Vaishnavi and Kuechler	X		X	X	X	X		
Cole et al.	X			X	X		X	
Manson	X		X	X	X	X		
Peffers et al.	X		X	X	X			X
Gregor and Jones	X	X	X	X	X			
Baskerville et al.	X		X	X				
Alturki et al.	X	X	X	X	X			X

Source The authors

The majority of authors also propose a suggestion step, in which specific features and requirements of the artifact to be subsequently developed are identified (Alturki et al. 2011; Baskerville et al. 2009; Bunge 1980; Eekels and Roozenburg 1991; Gregor and Jones 2007; Nunamaker et al. 1991; Peffers et al. 2007; Takeda et al. 1990; Vaishnavi and Kuechler 2011; Walls et al. 1992). They also suggest an evaluation step, which also demonstrates concern for rigor in the conduction of research in addition to the importance of the developed solution that satisfies the problem requirements (Alturki et al. 2011; Bunge 1980; Cole et al. 2005; Eekels and Roozenburg 1991; Gregor and Jones 2007; Nunamaker et al. 1991; Peffers et al. 2007; Takeda et al. 1990; Vaishnavi and Kuechler 2011; van Aken et al. 2012).

Other elements emerge by a few authors. One such element is a literature review step to search for existing solutions to a particular class of problems and to identify well-established theories that can serve as a basis for the research developed under the *design science* paradigm (Alturki et al. 2011; Gregor and Jones 2007; Walls et al. 1992).

Another element that is indicated by some authors is a formal decision-making process, in which the researcher defines the optimal solution or the most suitable artifact for solving the problem (Eekels and Roozenburg 1991; Manson 2006; Takeda et al. 1990; Vaishnavi and Kuechler 2011). A step focused on learning, reflections on the study, and the communication of the findings of the study, which can ensure that other researchers or interested parties can apply the generated knowledge, was also suggested by some authors (van Aken et al. 2012; Alturki et al. 2011; Cole et al. 2005; Peffers et al. 2007).

Once the different proposals for conducting research according to *design science research* have been presented, a comparison will be performed between *design science research* and two commonly used methods of research in the area of management, case study, and action research.

4.3 Characterization of Design Science Research, Case Study, and Action Research

In the search for methodological rigor in scientific studies, the researcher must define the research method at the beginning of his/her activities. In addition to defining the research method, the reasons for its selection should also be presented and justified. The relationship and importance of these choices were discussed in previous chapters using the pendulum example, which represented the various elements that must be considered when conducting scientific research.

When selecting the research method, three main points need to be considered: (i) the method used should address the research question, (ii) the method must be recognized by the scientific community, and (iii) the method should clearly demonstrate the procedures that were adopted for the research. The main functions of these elements are to ensure the robustness of the research and its results.

To assist the researcher in selecting the research methods, Table 4.2 includes a brief comparison between two different methodological approaches used in management research—case study and action research—and *design science research*. Note that this table does not attempt to be exhaustive but instead demonstrates the main differences and similarities among these methods.

The main differences among these three research methods are their objectives, the form used by the method to evaluate the results, the role of the researcher in conducting activities, the potential for the generalization of knowledge, the potential (although not mandatory) collaboration between the researcher and the persons researched, and the requirement of an empirical basis for the study. *Design science research* is based on the concepts of *design science,* whereas the action research and case study are linked to the natural and social sciences.

However, depending on the purpose of the research, the joint use of these methods and the use of the case study and action research under the *design science* paradigm are not disregarded. For example, Sein et al. (2011) proposed the integration of action research and *design science research* in a method referred to as *action design research*. When action research is applied under the *design science* paradigm, it can contribute to the construction of artifacts in cases where development is dependent on the interaction of the participants of the research or when evaluation can only be performed in the context of the organization and with the involvement of people within the environment under study.

Although this book proposes a distinct difference between *design science research* and action research, no consensus is evident in the literature, particularly regarding the boundaries between these methods. Järvinen (2007), for example, compares action research and *design science research* and concludes that these methodological approaches are extremely similar. Iivari and Venable (2009) present a reflection that distinguishes between these approaches that extends from paradigmatic assumptions to operational issues. Sein et al. (2011) proposed the integration of these approaches in *action design research* and depict its application.

This discussion can be clarified by simply distinguishing the ends (objectives) and means of the research. If the ends (objectives) of the research are to describe, explain, or predict, then it can be inferred that the case study and action research are suitable approaches as traditionally presented and defended, whereas *design science research* does not enable these objectives to be achieved.

Using traditional methods but under a different paradigm, van Aken (2004) depicts the possibility of using the case study that is based on *design science* according to the study by Womack et al. (1990) on the global automotive industry. In this study, several artifacts have been formalized (methods and instantiations), such as *Kanban*, production synchronization, and just-in-time production. In the situation explained by van Aken (2004), the case study accomplishes two purposes: to advance the theoretical knowledge of the study area and to formalize effective artifacts that may be useful to other organizations.

This comparison shows that *design science research* is the most appropriate research method when the aim of the study is to design and develop artifacts

Table 4.2 Characteristics of the different research methods

Characteristics	Design science research	Case study	Action research
Objectives	Develop artifacts that enable satisfactory solutions to practical problems	Assist in the understanding of complex social phenomena	Solve or explain problems of a given system by generating practical and theoretical knowledge
	Design and recommend	Explore, describe, explain, and predict	Explore, describe, explain, and predict
Main activities	Define the problem Suggest Develop Evaluate Conclude	Define conceptual structure Plan the case(s) Conduct pilot Collect data Analyze data Generate report	Plan actions Collect data Analyze data and plan actions Implement actions Evaluate results Monitor (continuous)
Results	Artifacts (constructs, models, methods instantiations) and improvement of theories	Constructs Hypothesis Descriptions Explanations	Constructs Hypothesis Descriptions Explanations Actions
Type of knowledge	How things should be	How things are or how they behave	How things are or how they behave
Researcher's role	Builder and/or evaluator of the artifact	Observer	Multiple, due to the action research type
Empirical basis	Not mandatory	Mandatory	Mandatory
Researcher-researched collaboration	Not mandatory	Not mandatory	Mandatory
Implementation	Not mandatory	Not applicable	Mandatory
Evaluation of results	Applications Simulations Experiments	Comparison against the theory	Comparison against the theory

(continued)

Table 4.2 (continued)

Characteristics	Design science research	Case study	Action research
Approach	Qualitative and/or quantitative	Qualitative	Qualitative
Specificity	Generalizable to a certain class of problems	Specific situation	Specific situation

Source Based on Lacerda et al. (2013)

and prescriptive solutions in a real or simulated environment. However, when the research objectives are focused on exploration, description, or explanation, case study and action research are the most suitable methods.

However, regardless of the selected research method, all methods must ensure the validity of research. Therefore, the following section is developed.

4.4 Validity of Research

This section discusses the validity of research that employs *design science research* as a method. According to Pries-Heje and Baskerville (2008), the validity of *design science* research must be established from the evaluation of the developed artifacts. When evaluated, these artifacts must show that they satisfy the required conditions to achieve the desired and expected objectives, that is, that they completely accomplish their function (Pries-Heje and Baskerville 2008).

Chakrabarti (2010) suggests that some validation methods lack sufficient empirical foundations. However, validity is a key factor in the support of the research to facilitate the practical application of research (Chakrabarti 2010). According to Mentzer and Flint (1997), the validity of research can be characterized as a set of procedures that are used to ensure that the research conclusions can be safely asserted.

As a validation method, d*esign science research* considers a set of procedures that ensure that the results generated by the artifact derive from the internal designed environment and the external environment for which it was developed. The following steps are proposed: (i) to accurately and explicitly define the internal environment, the external environment, and the objectives, (ii) to define how the artifact should be tested and (iii) to describe the mechanisms that will generate the results to be controlled/monitored.

In this section, an essential step for adequate validation of research that is based on *design science* is detailed: the evaluation of artifacts derived from *design science research*. According to Tremblay et al. (2010), research that is based on *design science research* cannot only focus on the development of the artifact and should demonstrate that the artifact can be effectively used to solve real problems (Tremblay et al. 2010).

Despite a specific evaluation step of the artifact, partial reviews of the results should be conducted in each expected step of *design science research* to ensure that the research advances toward the proposed objectives. Hevner et al. (2004) suggest five ways to evaluate an artifact: (i) observational (ii) analytical (iii) experimental (iv) testing, and (v) descriptive. Specific methods and techniques are proposed to evaluate the artifacts generated by *design science research* (Hevner et al. 2004). These groups are detailed in Table 4.3, including methods and techniques that can be used to evaluate the artifacts.

Observational evaluation, which is the first form of evaluation proposed by Hevner et al. (2004), is performed with the support of some elements of the case

Table 4.3 Methods and techniques for the evaluation of artifacts

Form of evaluation	Proposed methods and techniques
Observational	Case study elements: study the existing or created artifact in depth in the business environment Field study: monitor the use of the artifact in multiple projects
Analytical	Static analysis: examine the structure of the artifact for static qualities Architecture Analysis: study the fit of the artifact in the technical architecture of the complete technical system Optimization: demonstrate the optimal properties inherent to the artifact or demonstrate the limits of the optimization in the artifact behavior Dynamic analysis: study the artifact during use to evaluate its dynamic qualities (e.g., performance)
Experimental	Controlled experiment: study the artifact in a controlled environment to determine its qualities (e.g., usability) Simulation: execute the artifact with artificial data
Testing	Functional test (*black box*): implement the artifact interfaces to discover potential failures and identify defects Structural test (*white box*): perform coverage tests of some metrics for implementing the artifact (e.g., execution paths)
Descriptive	Informed argument: use the information of knowledge bases (e.g., relevant research) to construct a convincing argument about the utility of the artifact Scenarios: construct detailed scenarios for the artifact to demonstrate its utility

Source Adapted from Hevner et al. (2004, p. 86)

study and the field study. The following case study elements are suitable for this evaluation stage: case planning (for example, definition of the units of analysis), the methods for collecting and analyzing data and the final report of observations by the researcher.

The primary goal of observational evaluation is to determine how the artifact behaves in a comprehensive manner and in a real environment (Hevner et al. 2004). In this type of evaluation, the researcher acts as an observer and does not directly interact with the study environment.

Artifacts may also be evaluated by analytical methods and techniques, which is the second form of evaluation proposed by Hevner et al. (2004), in which the artifact, its (internal) architecture and interaction with the external environment is evaluated (Hevner et al. 2004). In this case, the primary goal is to assess the artifact's performance and how it can improve the system.

The third form of evaluation proposed by Hevner et al. (2004) is named experimental evaluation. Experimental evaluation may occur using controlled experiments, for example, in the laboratory or by simulation (Hevner et al. 2004). The simulation can be performed using computers and physical *mock-ups*. "Mock-ups are full-size models" (Gerszewski et al. 2009, p. 4) that represent a real environment to assess and demonstrate the behavior of the artifact to be evaluated.

The fourth form proposed by Hevner et al. (2004) for evaluation of artifacts is testing. Hevner et al. (2004) proposes two ways to perform this type of evaluation:

a functional test (*Black Box*) and a structural test (*White Box*), which are commonly used when addressing the development of artifacts in the field of information systems but can be easily adapted to artifacts from other areas. The *White Box* is a structural test and is based on the internal analysis of the software (Khan 2011), that is, the *White Box* evaluates how the system internally processes the inputs to generate the desired outputs (Khan 2011). The *Black Box* is a functional test that determines whether the system satisfies the desired parameters from the viewpoint of the user (Khan 2011). The user does not need to understand the internal structure of the system, only its functionality and utility.

The fifth form of evaluation proposed by Hevner et al. (2004) is named descriptive evaluation. The descriptive evaluation seeks to demonstrate the utility of the developed artifact. To demonstrate its utility, the researcher can use existing arguments in the literature or construct scenarios to demonstrate the utility of the artifact in different contexts (Hevner et al. 2004).

Note that other approaches for evaluating the artifacts exist in addition to the methods presented by Hevner et al. (2004). For example, the artifacts can be developed by the focus group technique. According to Bruseberg and Mcdonagh-Philp (2002), this technique can be used to support the development and the evaluation of the artifacts. Bruseberg and Mcdonagh-Philp (2002) explained that focus groups were used to develop software and evaluate software interfaces.

Focus groups comprise an appropriate technique for evaluating *design science research* because they guarantee a more comprehensive and collaborative discussion regarding the artifacts developed by the research. According to Bruseberg and Mcdonagh-Philp (2002), the focus group can be combined with other techniques to accomplish the following objectives: (i) support the discussions of interested groups, (ii) facilitate the triangulation of data, and (iii) assist in the development of new ideas about a given problem.

Focus groups also facilitate the critical analysis of research results and can generate new possibilities to obtain better solutions to problems. Tremblay et al. (2010) present two types of focus groups that can be used to evaluate the artifacts developed by *design science research*; these types and their main characteristics are shown in Table 4.4.

Table 4.4 Types of focus groups in *design science research*

Characteristics	Exploratory focus group	Confirmatory focus group
Objective	Achieve rapid incremental improvements in the creation of artifacts	Demonstrate the utility of the developed artifacts applied in the field
Role of focus group	Provide information that can be used to change the artifact and the focus group script Refine the focus group script and identify constructs to be used in other groups	The previously defined interview script to be applied to the working group should not be modified over time to facilitate comparisons between each participant focus group

Source Adapted from Tremblay et al. (2010)

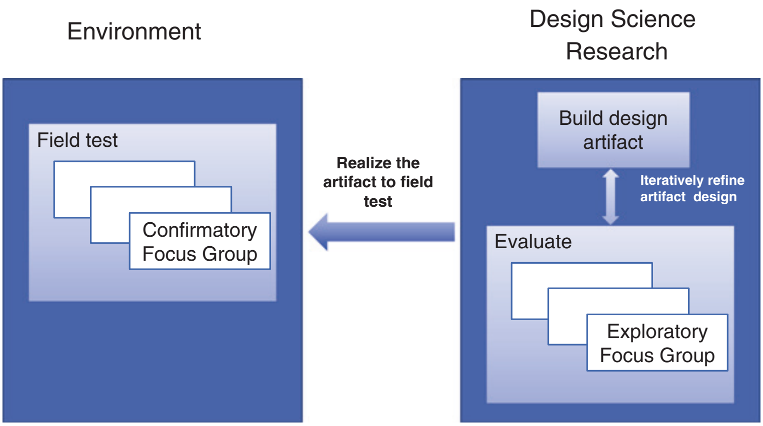

Fig. 4.19 Focus group in *design science research. Source* Tremblay et al. (2010, p. 603)

According to Tremblay et al. (2010), the exploratory focus group is the most suitable focus group for the evaluation of the artifact not only for its final evaluation but also for interim evaluations that may generate incremental improvements in the artifact.

Once the artifact is ready to be tested in the field (when necessary and/or desired), the confirmatory focus group is the most suitable focus group (Tremblay et al. 2010) because it can confirm the utility of the artifact within its field of application. Figure 4.19 schematically represents these concepts.

However, note that the choice of evaluation method may depend on both the artifact developed and the demands regarding the performance of the artifact. Consequently, the evaluation method should be directly aligned to the artifact and its applicability. A rigorous evaluation of the artifact and of the research results will contribute to the robustness of the work and ensure the reliability of its results.

According to Mentzer and Flint (1997), it is important to clarify that the use of sophisticated methods is not an assumption. Rigor is critical to prevent conclusions that are not supported by the research. Applying this concept to the *design science research*, rigor pertains to justification of the adopted procedures to improve the reliability of the artifact and its results regarding its application form.

This chapter suggests mechanisms that enable a detailed understanding of the produced artifacts and ensures the replication of research that employs *design science*. Replication is an important mechanism that ensures consistency and tests knowledge produced over time.

In the next chapter, two concepts that were previously discussed are presented: the class of problems and artifacts. Both concepts are critical to the discussion of *design science research*.

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Chapter 5
Class of Problems and Artifacts

> *An artifact can be thought of as a meeting point—an interface in today's terms—between an 'inner' environment, the substance and organization of the artifact itself, and an 'outer' environment, the surroundings in which it operates.*
>
> (Simon 1996, p. 06)

This chapter is organized into three sections. In Sect. 5.1, *the definitions and concepts related to the Class of Problems will be presented. In addition, examples of some Classes of Problems that are common to management will be provided.* Section 5.2 *addresses the concept and typification of the artifacts generated from the Design Science Research. Additionally, the definitions of each type of artifact, as well as the main characteristics that distinguish them, will be presented.* Section 5.3 *presents a logic that relates the artifacts generated from Design Science Research and the concept of the Class of Problems. Furthermore, the formalization of a possible research trajectory that is grounded on Design Science will be performed.*

5.1 Concept of Class of Problems

In his book *The Sciences of the Artificial*, Simon (1996) did not define what a Class of Problems was; however, he exemplified such classes. Classes of Problems can be an organization that guides the trajectory of knowledge development in the Design Science context. The nature of the artifacts itself can induce the formation of such classes, as can be observed in this chapter.

However, there have been few authors who have classified constructed or evaluated artifacts into a certain Class of Problems, even when Design Science Research has been used as the research method (Sein et al. 2011). In this sense, the main discussion regarding the need to define Classes of Problems for the proper performance of research based on Design Science was primarily presented by van Aken (2004), van Aken et al. (2012) and Sein et al. (2011).

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Classes of Problems, in turn, allow that the artifacts and therefore their solutions are not only occasional responses to certain problems in particular contexts (Venable 2006). These classes allow for the knowledge generated in a specific context, when generalized, to be classified into a particular Class of Problems, which can later be accessed by other researchers or organizations that have similar problems, in agreement with the statement that "Design-Science is not concerned with action itself, but with knowledge to be used in designing solutions" (van Aken 2004, p. 226).

In this sense, the knowledge generated from Design Science Research is generalizable and therefore can be classified into a given class of cases (van Aken 2004), understood as a Class of Problems. It is understood that the real problem and, therefore, the artifacts that generate satisfactory solutions for such problems are always unique in their context. However, both the problems and satisfactory solutions can share common characteristics that enable the organization of knowledge of a particular Class of Problems—thus enabling the generalization and advancement of knowledge in the area.

There is no conceptual definition of Class of Problems or a suggestion for its construction. This discussion, however, seems to be central because Classes of Problems could provide an alternative that could be used instead of considering only solutions that are primarily occasional and specific. Thus, we define Class of Problems as the organization of a set of problems, either practical or theoretical, that contain useful artifacts for action in organizations. Table 5.1 seeks to illustrate this concept of Class of Problems, considering the reality of the area of operations management in particular.

The definition of the concept of Class of Problems offers the possibility for the treatment of theoretical problems because a problem can also correspond to ways of testing a theory in organizational practice. It also offers the possibility of formalizing artifacts present in the practice of a given organization that must be evaluated in other environments. This feature also allows for the use of traditional research methods (Case Study, Action Research, Modeling, Survey) to formalize existing artifacts, i.e., these research methods can be conducted based on the logic and premises of Design Science.

These classifications regarding the Classes of Problems are similar to the application of Sein et al. (2011), who wrote that the definition of Classes of Problems should be established to support research. This support can occur from the conception of the research until the generalization of its results, aimed toward implementing the solution not only to a specific problem but also to a certain Class of Problems. For illustrative purposes, Fig. 5.1 provides the graphical logic for building Classes of Problems.

With an identified (theoretical or practical) problem, it is necessary to become aware of its impacts for an organization. In addition to the impacts, it is necessary to identify the objectives or goals needed to consider the problem satisfactorily resolved. This procedure consists of "awareness" and consideration of the problem.

From this awareness, it is necessary to perform a systematic literature review. A systematic literature review aims to establish the set of empirical solutions

Table 5.1 Examples of class of problems and artifacts

Class of problems	Artifacts
Production planning and control	Drum-Buffer-Rope (Goldratt 1984)
	Kanban (Ohno 1988)
	CONWIP (Spearman et al. 1990)
Cost measurement	Throughput Accounting (Goldratt 2006)
	Activity-based Costing (Cooper and Kaplan 1988)
	Production effort units (Allora 1985)
Strategic alignment	Model of Labovitz and Rosansky (1997)
	Balanced scorecard (Kaplan and Norton 1992)
	Model of Hambrick and Cannella Jr. (1989)
	Organizational fitness profiling (Beer and Eisenstat 1996)
Process mapping	Value stream map (Rother and Shook 1999)
	Mapping by production function mechanism (Shingo 1989)
	Architecture of integrated information systems ARIS (Scheer 2005)
Problem analysis and decision-making support	Thinking process (Goldratt 1994)
	Systems thinking and scenario planning (Andrade et al. 2006)
	Method for problem identification, analysis and solving (Kepner and Tregoe 1980)
Project management	Critical chain (Goldratt 1997)
	PERT/CPM

Source Authors, based on Lacerda et al. (2013)

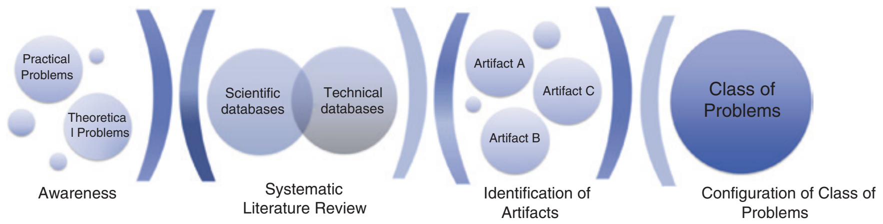

Fig. 5.1 Logic for building Classes of Problems. *Source* Authors, based on Lacerda et al. (2013)

known to date, as well as the theories that can support better understanding of the problem. The literature review aims to identify the artifacts that seek to find solutions to the problem in question. Once the artifacts are identified, it is possible to set up and structure the Class of Problems to which the artifacts belong. This procedure seems essential at this time because publications that consolidate Classes of Problems, tested artifacts and their solutions would be required, such as those in evidence-based medicine (van Aken et al. 2012; Huff et al. 2006), that remain unavailable in other areas.

5.2 Concept and Types of Artifacts

Artifacts can be understood as things that are manmade, i.e., something artificial according to the concepts defended by Simon (1969, 1996). However, although artifacts are considered artificial and therefore designed, based on the fundamentals of Design Science, artifacts are subject to natural laws, which are governed by traditional science (Simon 1996).

That said, it can be stated that artifacts are "artificial things [that] can be characterized in terms of functions, goals, and adaptation. Artificial things are often discussed, particularly when they are being designed, in terms of imperatives as well as descriptives" (Simon 1996, p. 28). Descriptives pertain to the communication and details of the main components and information about the artifact itself. They are discussed in terms of imperatives regarding the definition of the normative questions that involve the construction and application of this artifact.

Thus, "the fulfillment of purpose or adaptation to a goal involves a relation among three terms: the purpose or goal, the character of the artifact, and the environment in which the artifact performs" (Simon 1996, p. 28). Thus, "an artifact can be thought of as a meeting point—an 'interface' in today's terms—between an 'inner' environment, the substance and organization of the artifact itself, and an 'outer' environment, the surroundings in which it operates" (Simon 1996, p. 29). Therefore, an artifact is the organization of the components of the inner environment to achieve a particular goal in the outer environment (Simon 1996), as observed in Fig. 5.2.

Gill and Hevner (2011, p. 238), in turn, defined an artifact as "a symbolic representation or a physical instantiation of design concepts". For Gill and Hevner (2011), the design process consists of several layers, and these layers are strongly related to the characteristics and properties of the artifacts that are being developed. Figure 5.3 represents the layers of the artifact development process.

The first layer of the process of artifact development, defined by Gill and Hevner (2011), is called the *design space*. This first layer represents the set

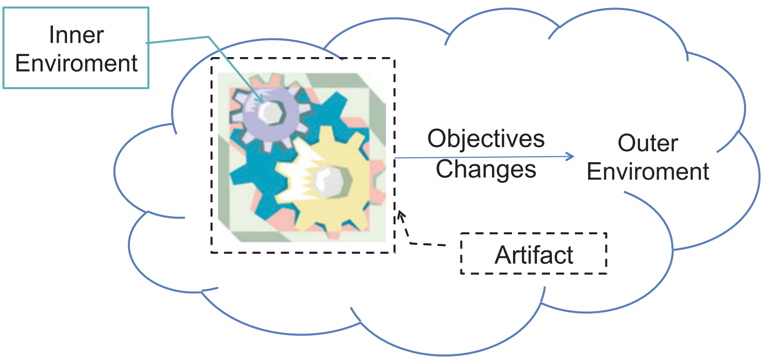

Fig. 5.2 Characterization of an artifact. *Source* Lacerda et al. (2013)

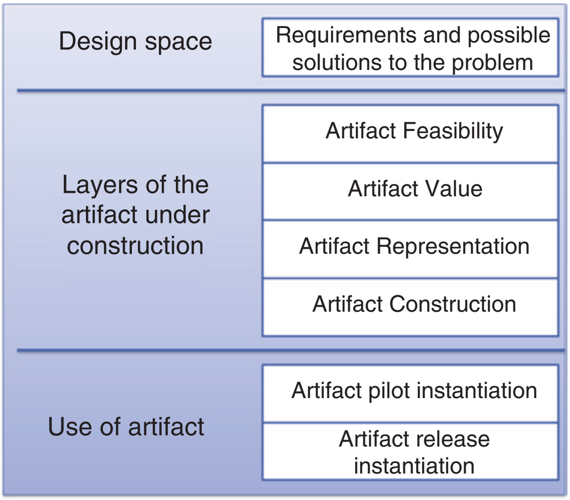

Fig. 5.3 Layers of the artifact development process. *Source* The authors, based on Gill and Hevner (2011, p. 239)

of possible solutions to the problem, i.e., in which the possible artifacts to be developed exist, as well as the requirements for their proper functioning (Gill and Hevner 2011). In this layer, the researcher can examine what exists and what does not yet exist relative to the problem that is being studied, as well as regarding the desired artifact to be developed.

The Design Space concept can be understood using the previously established concepts about Class of Problems. That is, before starting artifact design or development, it is necessary to determine what exists about this artifact in a given Class of Problems. With this determination, it is possible to ensure greater assertiveness of the researcher at the time that he/she proposes the artifact that can solve a certain problem situation.

Once a possible artifact is chosen for a solution, the researcher must focus on developing the artifact itself. The development of the artifact corresponds to the second layer proposed by Gill and Hevner (2011), and it consists of a number of sublayers. These sublayers are (i) artifact feasibility; (ii) artifact value; (iii) artifact representation; and (iv) artifact construction (Gill and Hevner 2011).

The identification of an artifact's feasibility aims to ensure that what is being proposed can indeed be implemented, considering all of the requirements for it to occur (Gill and Hevner 2011). Another sublayer concerns the definition of the artifact value, i.e., there is a need to demonstrate the benefits of this artifact to its users and why this artifact will be developed instead of any other (Gill and Hevner 2011). The third sublayer, called *artifact representation*, aims to determine the most appropriate format to communicate the artifact's concepts to the users (Gill and Hevner 2011). This representation can be graphical or an algorithm, among others. The fourth and last sublayer proposed by Gill and Hevner (2011) is the construction of the artifact itself. This construction can guide the artifact's users in its further implementation in the real context (Gill and Hevner 2011).

Table 5.2 Design science research products

Author	Design science research products				
Nunamaker et al. (1991)	–	–	–	Software	Theory building
Walls et al. (1992)	–	–	–	–	Design theories
March and Smith (1995)	Construct	Model	Method	Instantiation	–
Purao (2002)	Operational principles	–	–	Artifact	Emergent theory
van Aken (2004)	–	–	–	–	Design knowledge
Venable (2006)	Part of a technological solution	Part of a technological solution	Part of a technological solution	Computer-based system	Design theories
Gregor and Jones (2007)	Component of a design theory	Component of a design theory	Component of a design theory	Component of a design theory	Design theories

Source Alturki et al. (2011, p. 117)

The last layer presented by Gill and Hevner (2011) regarding the process of developing the artifact is focused on the use of the artifact. This layer is also subdivided into (i) artifact pilot instantiation and (ii) artifact release instantiation (Gill and Hevner 2011). This last layer aims to prepare the artifact for its implementation and use in the real environment. Moreover, based on the pilot, it is possible to return to the initial layers to improve the artifact that is being developed before releasing it for instantiation (Gill and Hevner 2011).

Once the central concepts of the artifacts are defined, they can be classified. However, the concepts regarding the types of artifacts (products) generated from the application of Design Science Research are still not uniform. Table 5.2, extracted from Alturki et al. (2011), summarizes the main authors who have characterized artifacts. In addition, this table attempts to group the artifacts by class, according to their similarity.

In this text, the classification of artifacts, originally proposed by March and Smith (1995), will be considered: construct, model, method, and instantiation. A fifth type of artifact consists of the theories grounded in Design Science (Cole et al. 2005; Gregor and Jones 2007; Venable 2006; Walls et al. 1992). There are several terms used to characterize design-based theories, i.e., there is no uniformity of terminology in this sense. Some of the terms used include Design Theory, Technological Rules, Design Rules and Design Propositions, among others (van Aken 2011; Gregor 2009; Venable 2006). In this book, *Design Propositions* will be the term used to represent this fifth artifact. The representation of artifacts and their types, which are Design Science Research products, is shown in Fig. 5.4.

According to the classification of March and Smith (1995), the first types of artifact are Constructs. Constructs (also called concepts) can be understood in the

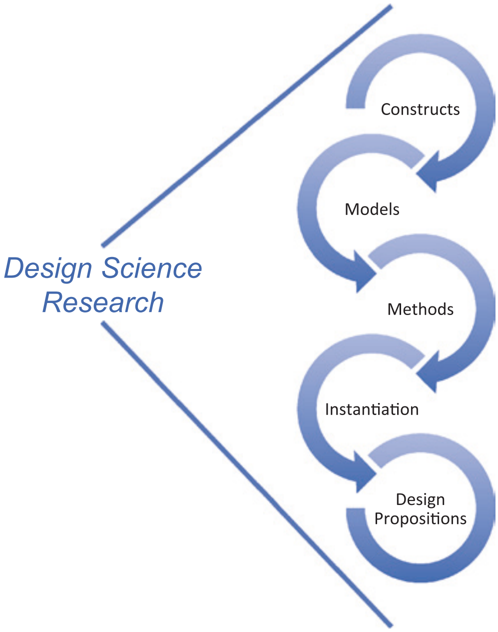

Fig. 5.4 Design science research products—Artifacts. *Source* The authors

context of Design Science Research as the vocabulary of a domain (March and Smith 1995). They constitute a type of conceptualization used to describe problems within the domain and to specify their solutions (March and Smith 1995). Conceptualizations are important for the advancement of science, both traditional science and Design Science (March and Smith 1995). Moreover, constructs "define the terms used when describing and thinking about tasks", and they can be valuable for both professionals and researchers (March and Smith 1995, p. 256).

Models are the second class of artifacts. A model can be understood, according to March and Smith (1995, p. 256), as a "set of propositions or statements expressing relationships among constructs". Models are considered representations of reality that present not only the variables of a given system but also their relationships. A Model can also be considered a description, that is, a representation of how things are (March and Smith 1995).

In Design Science, the main concern about Models is their utility and not the agreement of their representations with reality. Nevertheless, although a Model can sometimes be inaccurate regarding the details of reality, it should be able to capture the overall structure of reality, thus ensuring its utility (March and Smith 1995).

Methods are the third type of artifact proposed by March and Smith (1995). Methods can be understood as a set of steps necessary to perform certain tasks (March and Smith 1995). They can be graphically represented or encapsulated in heuristics and specific algorithms.

Method artifacts can be tied to Models because the steps of the Method can use parts of Models as the inputs that comprise them (March and Smith 1995).

Methods favor both the construction and the representation of the improvement needs of a particular system (March and Smith 1995). Moreover, they favor the transformation of systems, aiming for their improvement. Methods are typical creations of Design Science-based research.

The fourth type of artifact, also proposed by March and Smith (1995), is called instantiation: "An instantiation is the realization of an artifact in its environment" (March and Smith 1995, p. 258). Instantiations are the artifacts that operationalize other artifacts (constructs, models and methods) (March and Smith 1995). This operationalization seeks primarily to demonstrate the feasibility, as well as the effectiveness, of the constructed artifacts (March and Smith 1995).

Thus, instantiations inform the user on how to implement or use a particular artifact and its possible outcomes. Accordingly, instantiations can refer to a particular artifact or the articulation of several artifacts to produce results within a given context.

From this logic, it is possible to state that artifact instantiation consists of a coherent set of rules that guide the use of artifacts (constructs, models and methods) in a given real environment. This real environment consists of the boundaries of the organization or industry in which it is found, as well as the contours of the economic reality into which the organization is inserted. In this sense, the instantiation can play a particularly important role because it guides the use of other artifacts while considering multiple factors (economics, organizational and regional culture, competitive context, history of the organization), as well as the time/deadline to implement the solution.

The fifth and final type of artifact refers to the theoretical contributions that can be made by applying Design Science Research. It is important to clarify that in this context, when dealing with theoretical contributions, these contributions occur mostly in the Design Science realm. These artifacts are called *Design Propositions*. Design Propositions correspond to a generic template that can be used to develop solutions for a particular Class of Problems (van Aken 2011).

Thus, an artifact that is a theoretical contribution originating from Design Science Research would be in the form of a generalization of a solution to a particular Class of Problems. That is, knowledge of a solution could be applied to several similar situations, as long as their particularities were considered.

An example noted by van Aken (2004) and known in production engineering seems appropriate to illustrate a Design Proposition. This example, based on the concepts of the Focusing Process proposed by Goldratt and Cox (1993), is illustrated in Fig. 5.5.

In the case illustrated in Fig. 5.5, the Design Proposition addresses the Focusing Process, which proposes that systems should be managed based on constraints aiming to achieve the goal desired by the company (Goldratt 2006). The Focusing Process constitutes a general rule consolidated in the literature. This rule can be generalized to any other system that aims to increase its current and future gains. Therefore, a constructed artifact that seeks to transform inputs into outputs (outcomes) could be guided by the Focusing Process of the Theory of Constraints, for example.

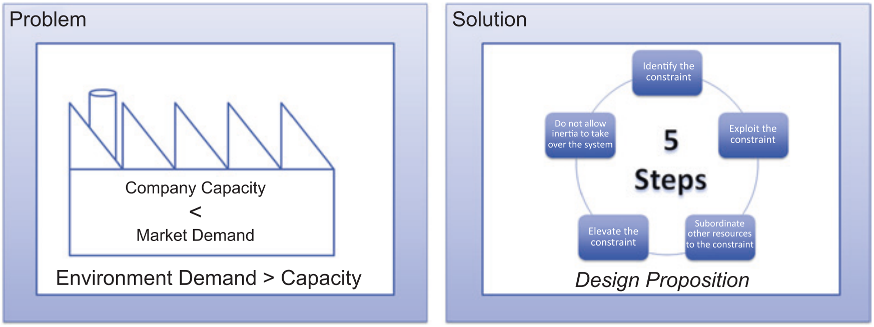

Fig. 5.5 Example of design proposition. *Source* The authors, based on van Aken (2004)

Fig. 5.6 Phases for theory development. *Source* The authors, based on Holmström et al. (2009)

Therefore, using as an example a company whose current capacity is less than the market demand, we can demonstrate that the company is not making more money because it is not adequately using its constraints. In this context, Cox III and Schleier Jr. (2010) recommended that the company should (i) identify its constraints; (ii) exploit the constraints; (iii) subordinate other resources to the constraints; (iv) elevate the constraints; and (v) not allow inertia overcome the system.

Citing a more generic example, also from van Aken (2004), a Design Proposition could be written as follows: “If you want to achieve Y in situation Z, then perform action X”. In other words, if it is necessary to achieve Y (a goal or problem to be solved) in situation Z (outer environment, context), then you should use X (the artifact, considering its internal organization and contingencies).

It is worth mentioning that the development of theories within Design Science, according to Holmström et al. (2009), can be divided into four phases, as shown in Fig. 5.6. These phases represent the process of building a theory, from its inception (new idea) to the phase of testing these ideas, transforming them into more simplified theories, and finally into formal theories.

The first phase of theory development based on Design Science is called Solution Incubation. The central goal of this first phase is to materialize the frameworks that represent as properly as possible the problem that is being studied (Holmström et al. 2009). Moreover, according to Holmström et al. (2009), based on this framework, the researcher should be able to suggest possible solutions to the problem of interest. These suggestions, once formalized, should allow for its implementation on a pilot level (Holmström et al. 2009).

The second stage of theory development, according to Holmström et al. (2009), is called Solution Refinement. During this stage of refinement, the previously developed solutions are tested in a real environment to determine whether the solution proposed by a researcher actually solves the problem (Holmström et al. 2009). These first two phases that support the building of a theory usually occur within organizations (Holmström et al. 2009). It is worth noting that professionals within organizations usually contribute only during these first two phases. However, this contribution, per se, is not considered to be a recognized scientific contribution (Holmström et al. 2009).

The third phase in the development of Design Science-based theories is called Substantive Theory or *Mid-range Theories*. This phase, according to Holmström et al. (2009), seeks relevance for the knowledge generated in phases 1 and 2, not only from a practical viewpoint but also from an academic viewpoint. This phase includes activities such as the evaluation of the artifact from the perspective of theory rather than practice (Holmström et al. 2009).

Mid-range theories depend on the context in which the solutions have been developed, and thus, they might not be considered general theories. In other words, Mid-range theories do not aim to make generalizations for all contexts but rather generalize theoretical concepts that might somehow contribute to the topic of a particular research program (Holmström et al. 2009).

Therefore, it is essential that the limits of the application/use of the artifact or the solution developed in phases 1 and 2 be well defined. This explanation of the limits of the proposed theory becomes critical because this theory will not necessarily work in the same manner in all contexts (Holmström et al. 2009). In fact, "the aim of Mid-range theories is to develop a deeper understanding of a theory in a specific context of application" (Holmström et al. 2009).

The fourth phase of theory development corresponds to Formal Theories. Formal Theories are focused on developing theories that can be used regardless of the context, thus differing from Mid-range Theories (Holmström et al. 2009). With Formal Theories, according to Holmström et al. (2009), the scientific contribution is more important than the practical relevance. Moreover, Formal Theories are usually generalizable (Holmström et al. 2009).

Finally, the next section seeks to formalize the logic of the artifacts discussed in this chapter, as well as a possible trajectory of research that uses the Design Science Research as a method.

5.3 A Trajectory for Research Development in Design Science

This section aims to clarify the relationship between the concept of Class of Problems and the artifacts generated by Design Science Research. Figure 5.7 was developed to explain this relationship and to formalize the logic between these concepts, as well as a possible trajectory of research grounded in Design Science.

The trajectory of research grounded in Design Science consists of four main steps. The first two steps occur during the performance of Design Science

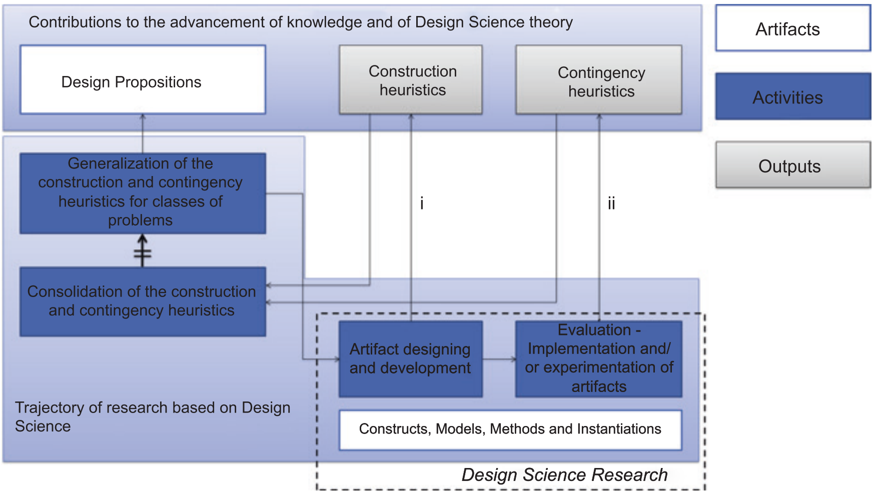

Fig. 5.7 Class of problems, artifacts and the trajectory of research grounded in Design Science. *Source* The authors

Research. The first of these steps refers to Artifact Designing and Development activities. The second step is the Evaluation, in which Experimentation can also occur or even the Implementation of the artifacts previously designed and developed. These two steps can result in artifacts, such as Construct, Model, Method and Instantiations.

At the moment that Artifact Designing and Development occur, the researcher can define the Construction Heuristics of this artifact (*i* arrow). That is, the researcher defines the requirements for the proper functioning of the inner environment of the artifact, according to the outer environment. For this step, the internal mechanisms and their organization are exposed, considering the desired effects on the natural or outer environment. Moreover, Construction Heuristics generate specific knowledge that can also be used to design new artifacts in the future.

When the researcher performs the step of Implementation or Experimentation of Artifacts, in turn, it is possible to formalize Contingency Heuristics (*ii* arrow). This knowledge is critical because it defines the limits of the artifact, its conditions of use, and the situations in which it will be useful. In other words, the formalization of Contingency Heuristics characterizes the outer environment of the artifact—that is, the context in which the artifact can be used and its performance limits, among other factors. The knowledge generated in this step can be used to design and build new artifacts.

Thus, once consolidated, both Construction and Contingency Heuristics should be generalized to a particular Class of Problems over time. It is worth noting that Consolidation and Generalization are not static steps in the trajectory of research development. Rather, they are dynamic and must occur over time. These steps can follow the logic shown in Fig. 5.6, particularly in steps 3 and 4.

Moreover, because there is a generalization of heuristics to a certain Class of Problems, this consolidated knowledge can be used by researchers when they are designing and developing new artifacts. These Classes of Problems, in turn, will organize both the artifacts developed and the knowledge about these artifacts, which extends from the internal organization of the artifact (Construction Heuristics) to its applicability and use limitations in the outer environment (Contingency Heuristics).

Once this generalization of heuristics to the corresponding Class of Problems is formalized, the Design Propositions can be defined, i.e., the fifth type of artifact presented in this text. This artifact contributes greatly to the advancement of knowledge in Design Science, either in the academic or organizational context. The artifact called Design Propositions differs from the other four because the results that it generates and also its construction are highly dynamic.

A Design Proposition should be built and monitored over time and not in a specific situation because Design Propositions are the results of saturation of the Construction and Contingency Heuristics that arise at the time of design and/or implementation of artifacts (constructs, models, methods, instantiations). Indeed, Design Propositions can guide/delimit the development of artifacts in a Class of Problems.

It is worth noting why the term “heuristic” was chosen to represent the contributions of Design Science for the advancement of knowledge. According to Koen (2003), heuristics are characterized by four elements: (i) a heuristic does not guarantee an optimal solution; (ii) a heuristic can contradict another heuristic; (iii) a heuristic reduces the time required to solve a problem; and (iv) the acceptance of a heuristic depends more on the context in which it operates than on a general parameter.

Moreover, Koen (2003) stated that the performance of the engineer is strongly related to the use of heuristics, considering that the engineer uses these heuristics to promote change, aiming to improve the performance of a system or an organization. It is worth noting that, according to Koen (2003), the engineer always considers the available resources (time and budget, among others) when promoting change.

Moreover, the validity of a heuristic depends on its utility, i.e., whether it works properly in the context for which it was designed (Koen 2003). Another interesting aspect of heuristics is that they “never dies; it just fades from use” (Koen 2003, p. 33), which means that a heuristic does not replace another by direct confrontation (as observed between theories in the traditional sciences, for example). A heuristic is only replaced when another that ensures a better outcome, in a given context, arises (Koen 2003). As noted, the concepts exposed by Koen (2003) regarding heuristics are strongly related to the concepts discussed in this dissertation regarding the application of Design Science concepts for problem solving-oriented research.

Once the Classes of Problems and artifacts, as well as the relationship between these concepts, are explained and defined, the next step should take place. Therefore, the next chapter will address a proposal to conduct research based on Design Science—that is, to conduct Design Science Research.

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Suggested Reading

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Chapter 6
Proposal for the Conduct of Design Science Research

> *Historically and traditionally, it has been the task of the science disciplines to teach about natural things: how they are and how they work. It has been the task of engineering schools to teach about artificial things: how to make artifacts that have desired properties and how to design.*
>
> (Simon 1996, p. 111)

This chapter proposes a method for conducting design science research. Recommendations for researchers who wish to use this research method are also presented. To develop this proposal, activities that may support research conduct with reliable and relevant results have been considered. It is important to highlight that this research method can be applied in other areas beyond management, with the objective of designing and constructing artifacts or prescribing solutions.

6.1 The Context of This Proposal

To develop research in areas, such as management, engineering, architecture, and design, the researcher often engages with the context of the subject under study. The context can involve anything from equipment to human resources. The interaction surely contributes to the development of knowledge that is both useful and applicable in the organizational context. Additionally, researchers must take into account the transdisciplinary nature of these areas of study because the real problem goes beyond the boundaries of disciplines. Therefore, knowledge production in this context arises out of Mode 2, initially presented by Gibbons et al. (1994) and conceptualized in previous chapters of this text.

Not only is knowledge production differentiated, but also, as a consequence, research objectives and the knowledge created are often different. Usually, research in the previously referenced fields focuses exclusively on exploring, describing, or explaining a problem. Moreover, it also addresses proposals to solve that problem. Therefore, the expected result of research may be to prescribe a solution or even to design an artifact. These are objectives that cannot be achieved when applying research methods based on traditional sciences.

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However, any scientific research, regardless of its objective, must also evidence its practical relevance or pragmatic validity. Logically, research must be rigorous so that its results are reliable, true, and—especially in the case of design science research—useful. Moreover, it is well known that traditional research methods have limitations regarding the study of a project or the creation of something new.

Considering all of these aspects, this chapter essentially focuses on proposing a method for conducting design science research. This proposal is grounded on the previously explained design science concepts.

Without a doubt, design science is an approach that can guide research aimed at designing or developing something new. This is the case because design science focuses on change and proposing solutions to existing problems, along with creating artifacts and generating solutions. Simon (1996) states that design science may contribute to the intellectual development of engineers, architects, and other professionals involved in the creation of objects or systems.

It is important to stress that the proposals suggested by this method do not aim to exclude other useful research methods. On the contrary, the precise goal of the method is to increase the number of available research methods in areas such as management, thus avoiding the need to use methodological frameworks that are inadequate or unfit for the object under study. Additionally, the proposition of this research method seeks to summarize and broaden some important issues for conducting scientific research.

6.2 Recommendations for Conducting Design Science Research

We considered several proposals for conducting design science research from different authors to ground the research method that is presented in this section. These proposals are also presented in Chap. 4.

The proposed method consists of 12 main steps (Fig. 6.1). The characteristics of each step, along with the recommendations to execute them and their outputs, are explained in Fig. 6.1. The continuous arrows indicate the direct order in which each step is executed. The dashed arrows show the possible feedback that may occur between the steps during the execution of the method.

Similar to the methods proposed by van Aken et al. (2012), Alturki et al. (2011), Baskerville et al. (2009), Bunge (1980), Cole et al. (2005), Eekels and Roozenburg (1991) and Peffers et al. (2007), the method for conducting design science research proposed here has as its first step the *identification of the problem* to be studied. The problem to be investigated by design science research primarily arises from the researcher's interest in (i) a new or interesting piece of information; (ii) an answer to an important question; or (iii) a solution to a practical problem or to a class of problems.

It is important to highlight that the problems studied by design science research must be, above all, relevant (March and Storey 2008). Therefore, at the moment that a problem is identified, the researcher must also justify the importance of

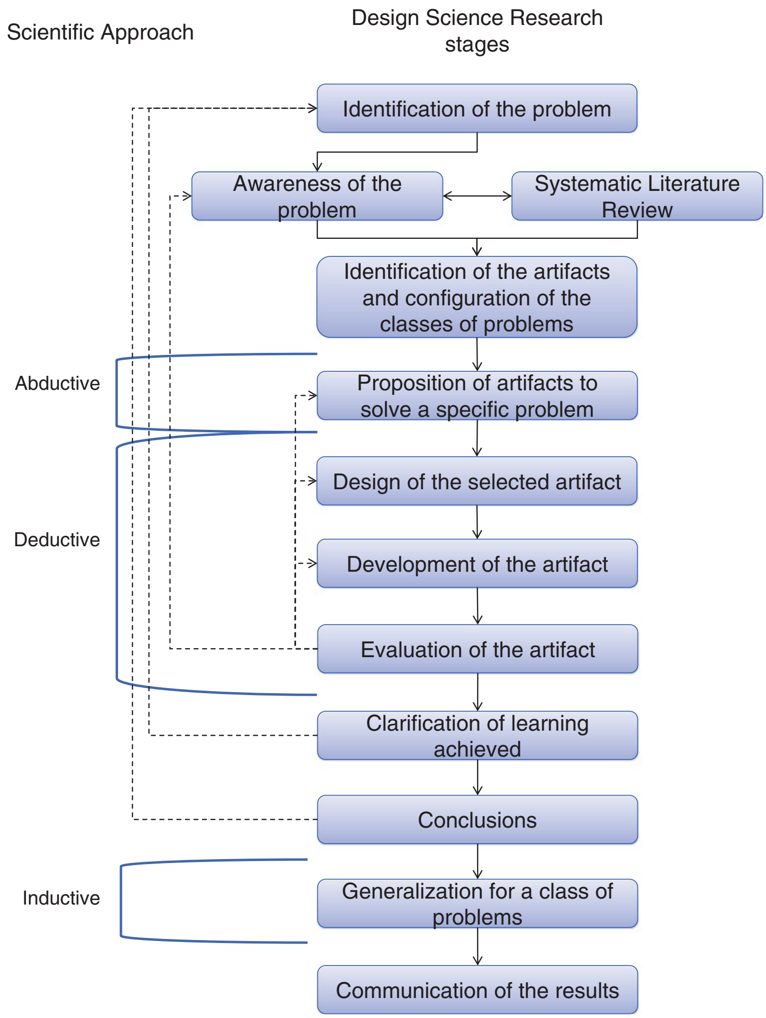

Fig. 6.1 Proposed method for conducting design science research. *Source* the authors

studying it (Booth et al. 2008). Additionally, once the problem is identified and its relevance is justified, the problem must be clearly and objectively understood and defined. The output of this step is the formalized research question.

The second step of the method addresses *awareness of the problem*, which is mentioned in the methods proposed by Manson (2006), Takeda et al. (1990), and Vaishnavi and Kuechler (2011). Simon (1996) states that before starting to solve a problem, some effort must be taken to understand it. In this step, the researcher must gather all possible information, making sure that he or she has an extensive understanding of every aspect of the problem. The researcher must understand the context of the problem, including its causes. Additionally, in this stage the functionalities of the artifact, its expected performance and its operational requirements must be considered.

The researcher must understand the problem from a broader perspective during the awareness-of-the-problem step (Simon 1996). To achieve this, different approaches can be used. For example, Romme (2003) proposes the systemic thinking approach.

One of the elements of systemic thinking that can be used in this step is systemic structure. Systemic structure shows potentially related effect-cause-effect relationships that can interact in a directly or inversely proportional manner, resulting in balancing or reinforcing effects (Andrade et al. 2006).

Systemic structure is a representation that not only shows factors that exist in the system but also (and above all) indicates existing interrelations (Senge 1990). Systemic structure also collaborates to identify the factors that are the most influential on a system's behavior over time (Senge 1990)

The construction of a systemic structure may help the researcher to see beyond the surface of the problem because it also favors the visualization of the causes of a particular system's behavior (Senge 1990). Once the causes of a problem are known, understanding it may be simpler (Morandi et al. 2013).

Another adequate approach to better problem awareness is the TOC (theory of constraints) thinking process. The thinking process and its tools were initially proposed by Goldratt in 1990 (Goldratt 1990) and later detailed in the book "It's Not Luck" (Goldratt 1994). This process starts from the assumption that it is possible to find problems/root causes by applying different tools (Goldratt 1994). Once the problems' root causes have been identified, they can be more easily solved.

Finally, the main output of the awareness step is the formalization of the aspects of the problem to be solved, considering its borders (i.e., the outer environment). In addition, to guarantee an adequate *awareness of the problem* stage, the researcher must understand and formalize the requirements that the artifact must fulfill to solve the problem.

To support the researcher's awareness of the problem to be studied, it is necessary for that researcher to consult knowledge bases (Alturki et al. 2011; Gregor and Jones 2007; Walls et al. 1992). This may be performed through a systematic literature review. The knowledge bases correspond to both the knowledge generated from traditional sciences and the one grounded on design science.

It is important to consult the knowledge bases of the traditional sciences because the artifact to be built will be always bound by natural and social laws (Simon 1996). Therefore, consulting only the knowledge developed under the design science paradigm will not be adequate to guarantee that the artifact will achieve its expected performance.

According to Gregor and Jones (2007), the consideration of existing knowledge, regardless of the type of science that generated it, helps the researcher to justify both the importance of building an artifact and why it will work. Therefore, a systematic literature review is essential because it will allow the researcher to use existing knowledge, thus allowing him/her to consult other studies that address the same or similar problems. A systematic literature review is adequate for the goals of this stage because it is a method that allows the researcher to access a large part of the knowledge necessary to develop the artifact and consequently, to solve the problem.

The fourth step of the design science research method is denoted *identification of the artifacts and configuration of the classes of problems.* Although this step is not clearly stated by other authors, it can be related to some of the elements proposed in the methods of Baskerville et al. (2009) and Walls et al. (1992).

The systematic literature review in the previous step helps the researcher to evidence potential artifacts and classes of problems that address problems similar to the one to be solved. However, it is possible for the researcher to find an artifact that is ready, ideal, and fully meets the need to solve the problem. In these cases, the research should be continued because the new artifact may bring better solutions than those already in existence.

If there is an already structured class of problems, the researcher needs to understand to the greatest extent possible the class and artifacts that belong to this group. The objective of identifying already-developed artifacts that have addressed problems similar to the one being studied is to allow the researcher to use best practices and lessons learned, acquired, and developed by other scholars. In addition, it ensures that the ongoing research is a relevant contribution to a certain class of problems. The configuration of the class of problems will define the reach of the artifact's contributions.

Moreover, the identification of existing artifacts (constructs, models, methods, instantiations, or design propositions) may help the researcher to be more assertive in his/her proposals for the development of new artifacts. It is also at this stage that the researcher begins to understand and define satisfactory solutions related to the artifact's performance.

Once the existing artifacts are identified, the classes of problems are structured and satisfactory solutions are formalized, the researcher must to initiate the fifth step of design science research, the *proposition of artifacts to solve a specific problem*. Other design science research methods, such as those proposed by Alturki et al. (2011), Baskerville et al. (2009), Bunge (1980), Eekels and Roozenburg (1991), Manson (2006), Takeda et al. (1990), Vaishnavi and Kuechler (2011), and Walls et al. (1992), also include this step.

This step is necessary because identifying classes of problems and developed artifacts addresses the visualization of possible generic artifacts to solve a generic problem. However, even these solutions must be adapted to the reality under study. At this point, the researcher must propose the artifacts, primarily considering their reality, context of performance, and feasibility, among other things.

Additionally, it is during this step that the researcher considers the situation in which the problem occurs along with possible solutions to modify and improve that situation. It is important to highlight that the objective is to find satisfactory solutions (Simon 1996) to the problem, and these solutions began to be delineated and understood in the previous step.

The artifact proposition process is essentially creative, therefore abductive reasoning, previously conceptualized, is adequate for this step. In addition to creativity, the researcher must use his/her previous knowledge to propose robust solutions that can be used to improve the current situation by solving the problem under study.

Once the proposals of artifacts are duly formalized, the sixth step of design science research can begin. This step, also addressed by van Aken et al. (2012), Alturki et al. (2011), Nunamaker et al. (1991), and Peffers et al. (2007), regards the *design of the selected artifact.* In other words, an artifact must be selected from among a previously proposed set, and it must be duly designed for the following steps of the method.

The design of the artifact must consider its internal characteristics and the external context in which the artifact will operate. In other words, this step must consider all of the components and internal relationships of the artifact's functioning, along with its limits and its relationship with the outer environment, i.e., the context in which the artifact will operate. These characteristics began to be defined in the *awareness of the problem* step. For designing the artifact, the researcher will also have to consider which solutions are satisfactory for the problem under study. These solutions have been characterized and formalized in the previous step.

It is important for the *design of the selected artifact* that the researcher describe all of the procedures that will be employed, not only for the artifact's construction but also for its evaluation. Moreover, it is in this step that the expected performance results of the artifact must be clearly stated. In other words, the performance requirements of the artifact must be described to ensure that a satisfactory solution will be achieved. These issues are also essential to guarantee the rigor of the research, so that it can be duly replicated and further confirmed by other researchers.

Once the design of the artifact has been completed, the next step, *development of the artifact*, can be performed. All of the authors who have proposed a method for conducting design science research have suggested a step to address developing the artifact (van Aken et al. 2012; Alturki et al. 2011; Baskerville et al. 2009; Bunge 1980; Cole et al. 2005; Eekels and Roozenburg 1991; Gregor and Jones 2007; Manson 2006; Nunamaker et al. 1991; Peffers et al. 2007; Takeda et al. 1990; Vaishnavi and Kuechler 2011; Walls et al. 1992).

The development step corresponds to the construction process of the artifact itself. In this step, the researcher builds the artifact's inner environment (Simon 1996). The construction of the artifact may use different approaches such as computational algorithms, graphical representations, prototypes, and scale models, among others.

It is important to highlight that this step of artifact development is not restricted to product development. Design science research may be useful for this goal, but it has a wider objective: to generate knowledge that can be applicable and useful to problem solving, improvement of existing systems and finally, to create new solutions and/or artifacts (Venable 2006).

At the end of the *development of the artifact* step, the researcher has two primary outputs. The first output is the artifact in its functional state. The second output consists of the construction heuristics that can be formalized from the artifact's development. It is important to remember that construction heuristics derived from the development of artifacts constitute one of design science's contributions to advancing knowledge.

Once an artifact has been built, it can be evaluated. This leads the researcher to the following step: *evaluation of the artifact.* In the evaluation step, the researcher observes and measures the behavior of the artifact toward a satisfactory solution of the problem (van Aken et al. 2012; Alturki et al. 2011; Bunge 1980; Cole et al. 2005; Eekels and Roozenburg 1991; Gregor and Jones 2007; Manson 2006; Nunamaker et al. 1991; Peffers et al. 2007; Takeda et al. 1990; Vaishnavi and Kuechler 2011). At this point, the requirements of the *awareness of the problem* step must be revised and then compared to the results of the artifact's evaluation to assess its adherence to these metrics.

This evaluation may be performed either in an experimental environment or in a real setting, and furthermore, it may be performed in numerous ways, some of them shown in Chap. 4. However, the artifact of the instantiation type must be applied and analyzed in the real environment. For this, elements of other research methods, such as action research, may be used because an interaction between the researcher, users, and members of the organization where the artifact is being instantiated most likely is necessary.

The outputs of the evaluation step including the duly evaluated artifact and the formalization of the contingency heuristics. The researcher will be able to state the limits of the artifact and its usage conditions through contingency heuristics, i.e., the relationship of the artifact with the outer environment in which the artifact will operate. The outer environment has been specified during the *awareness of the problem* step.

However, the artifact may not achieve the desired requirements for its application. In these cases, the researcher will have to identify the steps during which failures might have occurred. Once the step where the failure occurred has been identified, the research must be restarted from that point.

It is important to stress that the artifact's design, development, and evaluation steps can be performed using deductive logic. In this way, the researcher starts from existing knowledge to propose solutions for the artifact's construction.

In a case in which an artifact has achieved the expected results, following the evaluation step it is essential for the researcher to perform a *clarification of learning achieved* during the research process (van Aken et al. 2012; Cole et al. 2005). The objective of this step is to ensure that the research will be useful as reference and support for knowledge generation in both practical and theoretical fields. For this purpose, the researcher must explicitly identify the factors that have positively contributed to the research success along with the elements that have failed.

This learning, once formalized, is useful not only for the researcher but also to anyone who accesses the research. This can be useful both to other researchers and to the entire organizational community interested in the problem.

Later, in the tenth step of the method, the researcher must formalize a *conclusion*, the objective of which is to show the results of the research and the decisions made during its conduction (Eekels and Roozenburg 1991; Manson 2006; Takeda et al. 1990; Vaishnavi and Kuechler 2011). Additionally, the researcher must indicate the limitations of the research, which may lead to future studies.

It is possible that after the *clarification of learning achieved* and the *conclusions* steps, the researcher will have new insights. This will lead the researcher to new problems that must be studied, thus restarting design science research.

Once research has been completed, it is important for the developed artifact, even if it has been used for a particular situation, to be able to be *generalized for a class of problems* (Gregor 2009; Venable 2006). The artifact, together with its construction and contingency heuristics, must be generalized for a certain class of problems. This generalization enables the advance of knowledge in design science.

This generalization allows the knowledge generated in a specific situation to be later applied in similar situations that may be faced by different organizations. It is important to highlight that the generalization step must be performed based on inductive reasoning. In that reasoning process, the researcher seeks to generalize the solution of a specific problem to a certain class of problems.

Finally, *communication of results* is essential. This communication can be performed through publications in journals, trade magazines, seminars, and conferences, among others, with the goal of reaching as many interested parties as possible. These interested parties can be either in academia or in organizations. The communication and dissemination of the generated knowledge contributes significantly to the advance of general knowledge. Figure 6.2 summarizes the steps of design science research, as along with the outputs of each of its steps.

It is important to stress that the construction and contingency heuristics are not only the outputs of the artifact's development and evaluation steps, respectively, but also a reference for further research. In other words, the heuristics, once

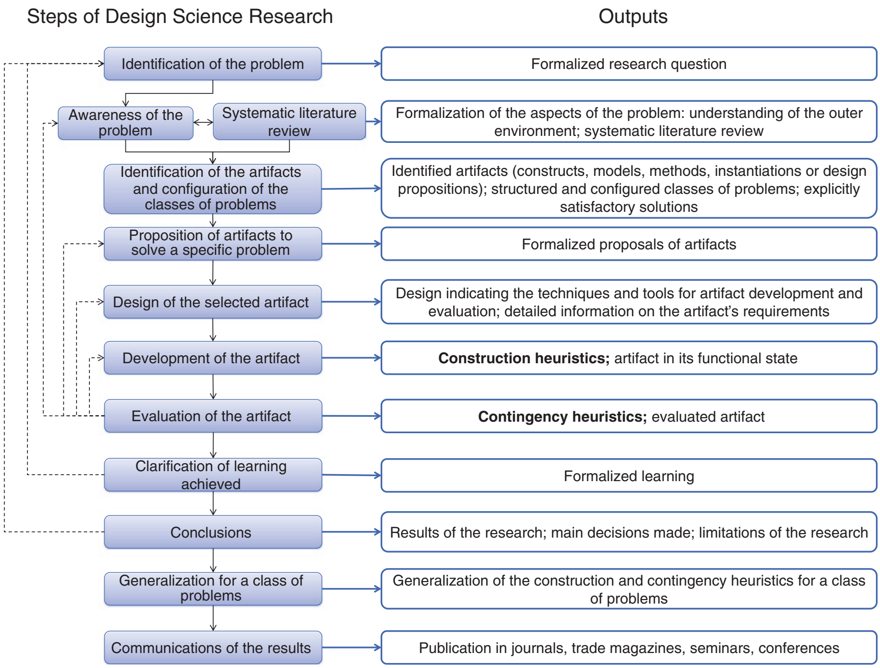

Fig. 6.2 Design science research steps and their outputs. *Source* the authors

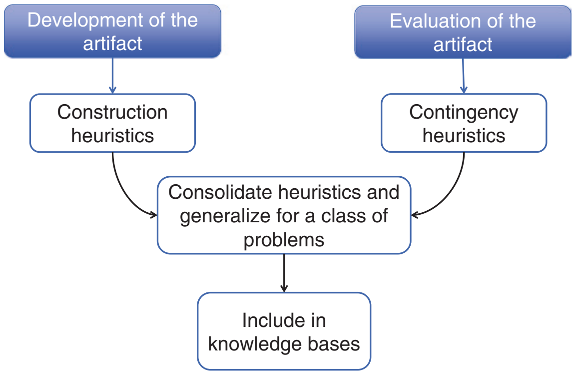

Fig. 6.3 Contribution of construction and contingency heuristics. *Source* the authors

consolidated and generalized, can be classified according to the class of problem to which they belong. These classes of problems, and sometimes the artifacts themselves, will be available in the knowledge bases. Therefore, these heuristics can be identified and used by other researchers for conducting new research. Figure 6.3 shows the representation of this path.

Finally, for research grounded on the design science research method to be rigorous, the researcher must follow all of the prescribed steps, paying attention to the outputs of each step, and formalizing a research protocol. This protocol must show in detail all of the researcher's planned activities during the research and the perceptions and insights that may arise during its execution. It is also essential that this document be continuously updated, so the researcher can record what occurred as expected and what had to be changed to guarantee the success of the work.

The research must be reliable and valid, meaning that the researcher's notes must always be accurate. Reliability is a core criterion for high-quality research, and a research protocol may help to achieve this objective. Yin (2013) states that reliability is essential because it demonstrates that the activities performed in a certain study can be repeated with the same results.

Therefore, the protocol must be robust enough to guarantee that other researchers will be able to successfully replicate the research. In other words, those interested in constructing or using the artifact will be able to do so successfully with access to the research protocol.

Additionally, to achieve rigor in the research grounded on design science, some elements must be considered to ensure the quality of the research. These elements are materialized in a list of parameters that aim to ensure the rigor of design science research. Figure 6.4 shows these parameters.

The parameters shown in Figure 6.4 are based on the concepts and fundamentals of design science and design science research. If a researcher pays attention to these issues, it will be possible to ensure that his research will have the required rigor so that its results will be considered reliable.

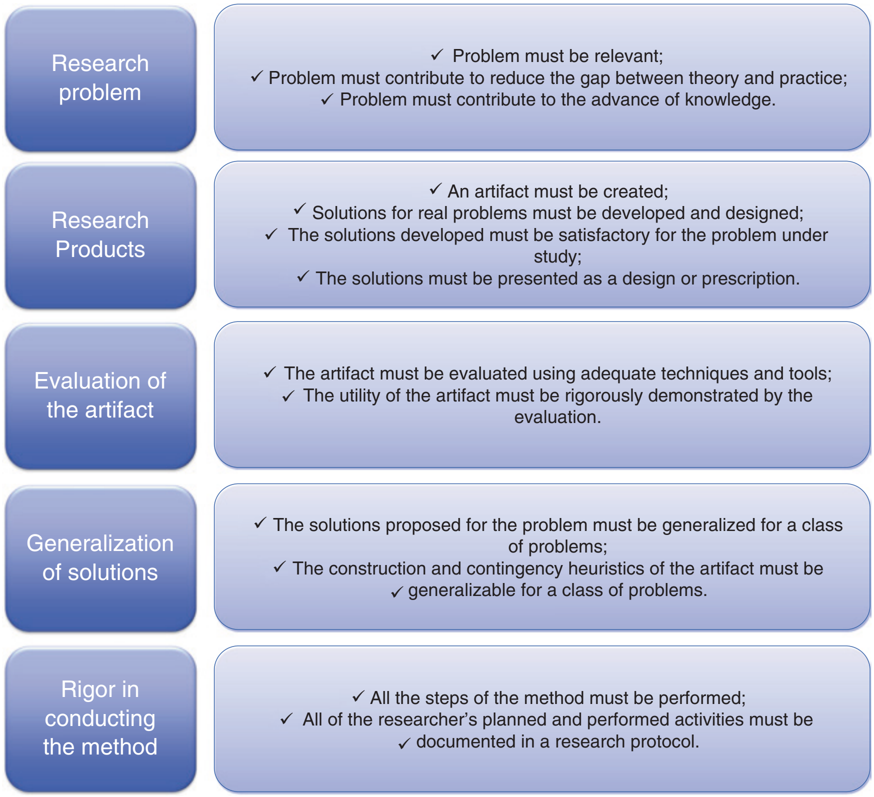

Fig. 6.4 Parameters to assess the rigor of design science research. *Source* the authors

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Chapter 7
Systematic Literature Review

The knowledge of the world is only to be acquired in the world, and not in the closet.

(Philip Chesterfield)

This chapter presents a method that can be applied to perform a Systematic Literature Review. The Systematic Literature Review is a critical step in conducting scientific research. This chapter focuses particularly on the importance of this step for research conducted under the Design Science paradigm.

7.1 Definition, Origins and Needs

Research can be understood as a systematic investigation with the aim of developing theories, establishing evidence and solving problems. For that purpose, it is important that the researcher be aware of what was previously researched, how it was researched, what results were found and, perhaps most importantly, what has not yet been researched (Gough et al. 2012).

As the volume of primary studies accumulates, the difficulty of remaining up-to-date on what has already been researched and published increases, even for researchers who are focused on a very specific subject. Therefore, Saunders et al. (2012) propose that the entire research project should consider a systematic literature review as one of its steps. Seuring and Gold (2012) reinforce that a systematic literature review is crucial to allow the desired information to be "mined" from an increasing volume of published results, sometimes similar and at other times contradictory.

Systematic literature reviews are secondary studies used to map, find, critically evaluate, consolidate and aggregate the results of relevant primary studies on an

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issue or specific research topic, as well as to identify gaps to be filled, resulting in a coherent report or synthesis (Gough et al. 2012; Kitchenham 2010; Seuring and Gold 2012; Tranfield et al. 2003). The term **systematic** means that the review should be performed according to an explicit, planned, responsible and justifiable method, similarly to the expectations of primary studies. This method should be planned to ensure that the review will be unbiased, accurate, auditable, replicable and updatable (EPPI Centre 2013; Gough et al. 2012; Kitchenham 2010). The accuracy and transparency of the process are seen as an advantage of systematic reviews (Dixon-Woods et al. 2006).

Another key feature of a systematic literature review is that the **synthesis** should be much more than a collection of the different elements researched. It is expected that the consolidation and aggregation of the results of primary studies should result in new knowledge (EPPI Centre 2013; Gough et al. 2012).

The use of systematic literature review is not a recent approach: according to Dixon-Woods et al. (2006), efforts to formalize and develop methods for literature review and synthesis of evidence occurred in the seventeenth century. Although the approach is strongly associated with the biomedical sciences, Littel et al. (2008) note that the first reviews can be found in the areas of education and psychology. The authors also note the emergence of meta-analysis—a set of statistical techniques used to synthesize the results of a systematic review—in association with the work by Karl Pearson in 1904 to synthesize the results of several studies on typhoid fever. New applications emerged in the 1970s in social and behavioral sciences studies; in the following decades, the authors identify as milestones the publication of the work of Light and Pillemer—*Summing up: The science of reviewing research*—in 1984 and the first edition of the *Handbook of Research Synthesis*, by Cooper and Hedges, in 1994. Another significant milestone is indicated by Dixon-Woods et al. (2006), namely the publication in 1992 by Altman et al. that illustrated how informal reviews and reviews based on single studies resulted in inefficient recommendations for the treatment of myocardial infarction.

The increasing number of systematic reviews since the mid-1990s, especially in the areas of the social, behavioral and health sciences, is associated with the movement toward evidence-based practices (Littel et al. 2008). These evidence-based practices have been incorporated into other areas of knowledge (Kitchenham 2010; Van Aken and Romme 2009), contributing to the increasing use of systematic literature reviews. A search on the MEDLINE/PubMed database returns more than 50,000 results for the term "systematic review", while Google Scholar features over 40,000 results using the same term.

A proper systematic literature review brings benefits to researchers. First, any single study may exhibit failures due to how it was designed, conducted or reported, and even a study that has been correctly conducted may have atypical results or limited relevance. For this reason, it is more appropriate that decisions be based on a broad set of studies, ideally including all relevant studies, rather than on individual studies or a limited set of studies. Thus, systematic reviews provide a comprehensive and robust view that allows researchers to keep abreast of what has been studied in their areas of interest. New research results can be better interpreted if grounded in the literature framework, which allows them to confirm, reject, contrast or complement findings from previous research. New research that does not consider the results of previous studies may result in unnecessary, inappropriate, irrelevant or even unethical works (Gough et al. 2012; Seuring and Gold 2012). Once one understands the concept and relevance of a systematic literature review, the proposed methods for conducting it must be analyzed.

7.2 Method for Constructing the Research Base

Although there is no single method for conducting a systematic literature review, certain steps are included in the methods described by several authors (Cooper et al. 2009; Gough et al. 2012; Khan et al. 2003; Smith et al. 2011), as depicted in Fig. 7.1. There is a common core that includes the search, selection and quality evaluation of the studies to be considered, although the method presented by Smith et al. (2011) is designed for the systematic review of other systematic reviews. Although no step aimed at defining the review issue is clearly presented in their method, it is present in their text when the author states that "the objective and the reasons for conducting a systematic review of reviews should be made explicit at the start of the process" (Smith et al. 2011, p. 2). Likewise, the synthesis of the

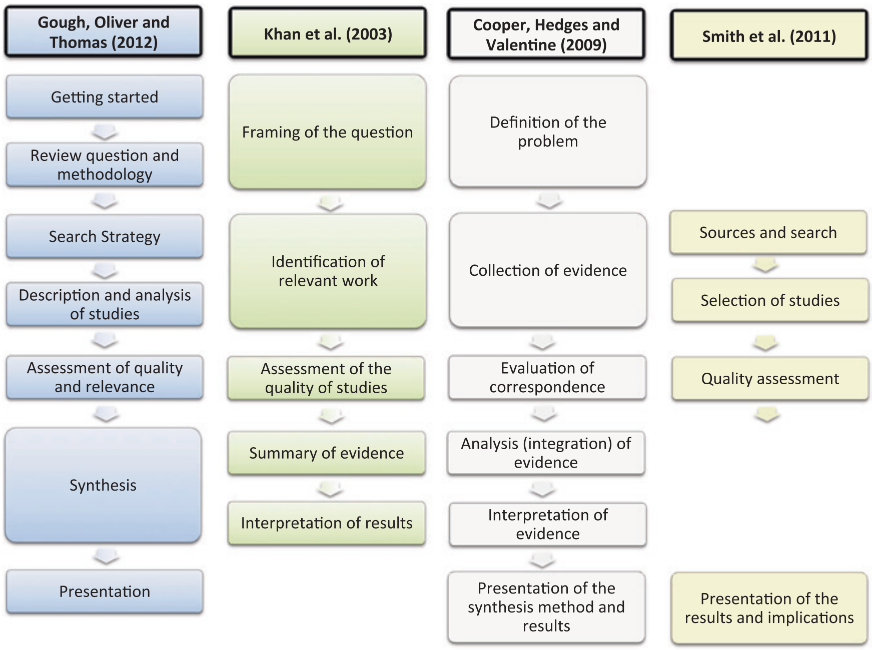

Fig. 7.1 Steps of the systematic review method. *Source* The authors

results is not explicitly addressed but can be considered as part of the presentation of the results because the authors mention the need to organize the results before their presentation (Smith et al. 2011). Regarding the presentation of results, only Khan et al. (2003) make no explicit reference to this step.

Although it does not explicitly appear in any of the proposed and researched methods, the relationship with the stakeholders is an issue that must be considered throughout the systematic review process, especially, but not exclusively, when the objective is the development of public policies (Rees and Oliver 2012).

Another aspect that has not been included as a step is the selection of the work team to conduct the systematic review. According to Abrami et al. (2010), a careful and thorough systematic review often requires time and resources. Therefore, it is necessary to evaluate the need to form a work team prior to defining the research strategies to be used.

Hence, a method is proposed that seeks to build and expand on the steps described by the studied authors. The steps common to the methods described are kept, and steps regarding the selection of the work team and the relationship with stakeholders are included. The stakeholders can be included both as input suppliers for the review process and in the role of customers of the final result. Considering all these factors, Fig. 7.2 shows the steps that comprise the proposed method for conducting a systematic literature review.

The following sections detail each of the steps, beginning with a discussion of the role of stakeholders, a subject that receives more emphasis due to not being explicitly addressed in the methods previously presented. Then, the various aspects involved in the definition of the review question are addressed along with the importance of developing a conceptual framework to enable the definition of the best work team and research strategies to be adopted. This subject is followed by the topic of the search for primary studies, detailing possible search sources

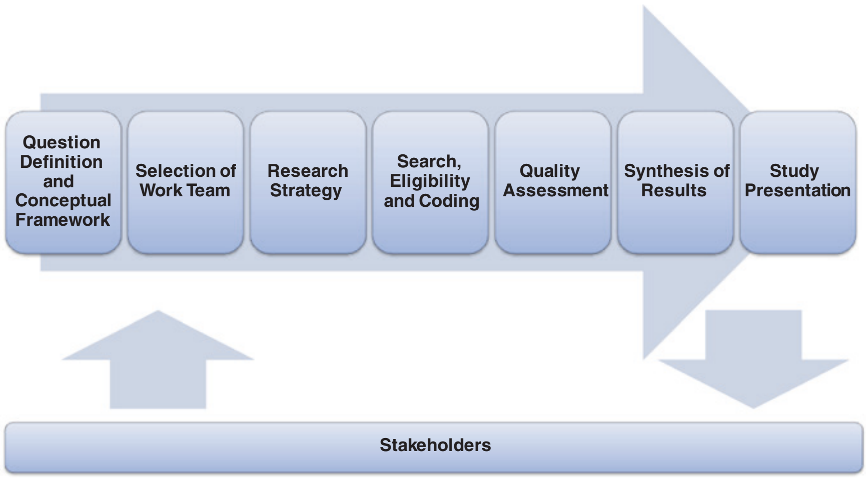

Fig. 7.2 Systematic literature review method. *Source* The authors

and strategies for minimizing bias, the selection process and the coding. The next section is a discussion on the quality assessment step to evaluate the selected studies, and the concluding section presents the various tools available for the synthesis of results and presentation of the study.

7.2.1 Stakeholders

Social and governmental policies, professional decisions and recommendations for medical treatment, among other issues, are often based on systematic literature reviews in a movement called evidence-based decision-making. Therefore, it seems logical that the people who will make decisions based on the review results and the people who will be affected by these decisions, as well as the people who may contribute to its construction, should be considered as interested parties or stakeholders (Keown et al. 2008; Rees and Oliver 2012).

The systematic review process is influenced by the different perspectives of the people who participate in it. Stakeholders can influence research at virtually all stages, from the definition of the review question to the dissemination of the study results (Keown et al. 2008; Rees and Oliver 2012; Schiller et al. 2013).

Stakeholder participation in defining the review question occurs particularly in cases when the systematic review is funded and when it is necessary to identify what these stakeholders consider to be important (Rees and Oliver 2012). However, this practice can and should be used in other cases of systematic review to increase the alignment of the process with the interests of the stakeholders and the likelihood that the result of the review will be subsequently considered and used (Keown et al. 2008; Lavis 2009).

Different perspectives can also be found both within the group that conducts the review and among all parties consulted during the process. The definition of the strategy, criteria and search sources, the selection of studies and the synthesis process are directly influenced by the experience and knowledge of the parties involved (Rees and Oliver 2012).

The team conducting the review may also avail themselves of the knowledge and experiences of the stakeholders who contribute to the process. Therefore, the involvement of stakeholders in the review process can occur more actively, by contributing experience and knowledge in various fields such as organizational knowledge, practical knowledge of the topic being researched and experience in the conduction of systematic reviews. This knowledge can be used a priori, to suggest search terms and sources as well as relevance criteria for the eligibility of primary studies or in the form of the synthesis of results, or a posteriori, to assess the relevance of the selected studies (Keown et al. 2008; Rees and Oliver 2012).

At the end of the process, it is important that the review results be presented to the stakeholders, especially to stakeholders who have provided input during the early stages. In this step, the goal of the review team is to obtain feedback on the clarity of the study as well as on the impact and usefulness of the results within the context of each stakeholder. Additional questions can be addressed at this time, such as suggestions on ways to disseminate the study and the identification of other potential audiences (Keown et al. 2008).

The stakeholders' involvement brings benefits to the systematic review process, such as a better alignment of the review question, a broader and more inclusive literature search and a critical evaluation of the results produced. On their part, the stakeholders express satisfaction that the researchers consider their experience and tend to more often communicate the results in their areas of expertise (Keown et al. 2008; Lavis 2009).

However, this involvement can also introduce certain challenges, such as the tendency to being less scientifically rigorous about including suggestions from stakeholders, in addition to requiring more time and involvement by the review group. Another issue is the difficulty of identifying the main stakeholders and obtaining their participation. Normally, this process is guided by the intuition and knowledge of the review team, and the stakeholders' participation often occurs more by convenience than by a systematic and structured process (Keown et al. 2008; Schiller et al. 2013).

7.2.2 Review Question and Conceptual Framework

The first step in conducting any systematic review is to define the central topic. However, to perform this step correctly, it is important to understand that systematic reviews can vary in many dimensions, such as extent, breadth and depth, time and resources used. The extent of the search refers to the variety of works researched. A systematic review may be more extensive and cover a wider scope or may be less extensive and focus on a specific approach (Gough and Thomas 2012).

The type of question that the review aims to answer defines the breadth of the systematic review and consequently the broadness of the search criteria and the search strategies and sources. More open questions lead to broader reviews, whereas more closed questions lead to reviews with narrower breadth. It is worth noting that a review can begin as broad and then be complemented by other reviews that focus on specific topics, thus allowing a greater depth (Gough and Thomas 2012).

It is also important to understand that these dimensions are interconnected: that is, one cannot expect a deep and broad systematic review to be performed within a short amount of time. Thus, these dimensions must be considered when determining the review question (Gough et al. 2012; Oliver et al. 2012).

In addition to these dimensions, one must also consider the review strategy that will best answer the review question that motivated the study. More closed questions that seek to test a theory based on the collection of empirical observations—the deductive method—lead to the **aggregative** review, in which the results of primary studies are aggregated to obtain the results. Although usually associated with quantitative data, aggregative reviews can also use qualitative primary studies. The main characteristic of this type of review is that it seeks to determine the relationship or connection between two or more aspects of a phenomenon without concern for the goals, motivations and methodologies of the primary studies that produced these results. This type of review usually makes use of more homogeneous primary studies (Gough et al. 2012; Sandelowski et al. 2012).

Open questions designed to explore a topic more broadly are best answered by means of a **configurative** review. In this case, the review questions tend to be answered with qualitative data gathered from more heterogeneous primary studies, which are interpreted and explored throughout the review to generate and explore the theory—the inductive method. In this case, the main objective of the review is the arrangement of several individual results into a coherent theoretical rendering (Gough et al. 2012; Sandelowski et al. 2012).

Although presented above in binary form, reviews may have different degrees of aggregative and configurative aspects. For this reason, Fig. 7.3 represents the overlapping review strategies with their respective characteristics. This same image will be repeated later when the processes of searching, categorization and synthesis are addressed (Gough and Thomas 2012).

Once the central topic is defined, it is essential to clarify the review question and how it will be answered, that is, to define the scope of the review through the development of a conceptual framework. The conceptual framework can be understood as a skeleton for conducting research, a starting point that enables understanding of the review and its context and that can be developed, refined or confirmed during the course of the research. For aggregative reviews, this scope can be clearly defined a priori, while for configurative reviews, only key concepts are predefined (Oliver et al. 2012).

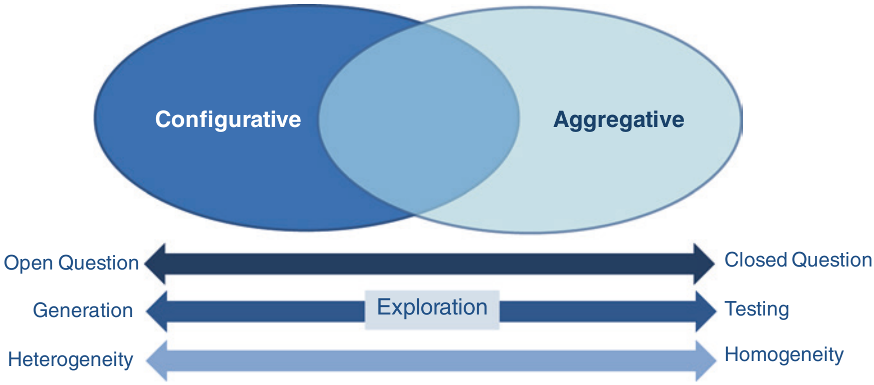

Fig. 7.3 Configurative and aggregative reviews. *Source* Adapted from Gough and Thomas (2012)

7.2.3 Work Team

While it is possible for a single person to perform a systematic literature review, such reviews are usually conducted by a team. The first reason is that a single individual rarely has all the necessary (technical and methodological) knowledge and skills for conducting such reviews. Even when review by one individual is possible, time can be a decisive issue for establishing a team because a systematic review can be very time-consuming. The quality of the review can also be increased when the search and eligibility of the studies and the coding of the results are performed independently by two people (Higgins and Green 2006; Oliver et al. 2012).

The establishment of the review team clearly depends on the review question, and the technical and methodological knowledge may be complemented by the participation of experts—identified or not as stakeholders—who act as consultants. It is essential that at least one team member should dominate the systematic review process from the methodological viewpoint. As for the technical knowledge of the central topic of the review, it is important to have several levels within the team: while experts can make important contributions—to search sources and criteria, eligibility criteria, the coding process and especially the synthesis process—individuals with less knowledge of the topic can challenge the assumptions and suppositions raised by the first group (Oliver at al. 2012).

The team must have a core group that remains throughout the process, but experts may only participate in a few steps. For instance, information technology professionals can help to develop search strategies (Beverley et al. 2003); librarians can be extremely useful in searching for and locating primary studies (Harris 2005); and statisticians can contribute to the synthesis steps of aggregative reviews based on quantitative data (Oliver et al. 2012).

7.2.4 Search Strategy

Systematic reviews involve managing a large amount of information. Before the search process is launched, one must invest in preparing the search strategy for primary studies (Brunton and Thomas 2012; Hammerstrøm et al. 2010). The search strategy starts from the review question and conceptual framework and aims to answer the following questions: What to search for? Where to search? How to minimize bias? Which studies to consider? What will the extent of the search be? One must also consider the available resources, from the review team to the technological resources, to develop a feasible strategy (Brunton and Thomas 2012; Hammerstrøm at al. 2010). These questions are not answered individually but are fully interconnected, as illustrated in Fig. 7.4.

The first step is to define the search terms, and for that purpose, a comprehensive conceptual framework is the first source for the choice of search terms (what to search for?), for the selection of search sources (where to search?) and for defining the criteria for inclusion and exclusion of studies (which studies to consider?). In turn, these actions are also interconnected because, depending on the selected source, it may be necessary to express the search terms differently—e.g., the language issue. Likewise, in the selection of search sources, inclusion and exclusion criteria must be considered: again, the language issue is crucial, but the issue of temporality is also important. The search strategy should also address the minimization of bias and the extent of the search, which is often limited by resource availability. The latter issues, in turn, also impact both the selection of search sources because only sources that the team can access may be selected, and the definition of the inclusion and exclusion criteria.

The extent of the search is an important decision in the development of the strategy. Although a systematic review must necessarily cover all relevant primary studies, an exhaustive search is often much more an intention than a reality because it is virtually impossible to ensure that all studies are located. Therefore, a strategy is considered to be comprehensive if it seeks to find the largest possible amount of relevant studies. This strategy is recommended for aggregative reviews. A saturation strategy aims to find sufficient primary studies for a coherent configuration of the topic being studied. Thus, the search for new studies extends to the point that they no longer contribute new concepts to the synthesis process. This strategy is the most suitable for configurative reviews (Brunton et al. 2012).

One advantage of a systematic review compared to other studies or even to expert opinion is the implementation of strategies that minimize the possibility of bias (Lundh and Gøtzsche 2008). Avoiding the occurrence of bias ensures that all relevant studies have been identified and considered (Brunton and Thomas 2012).

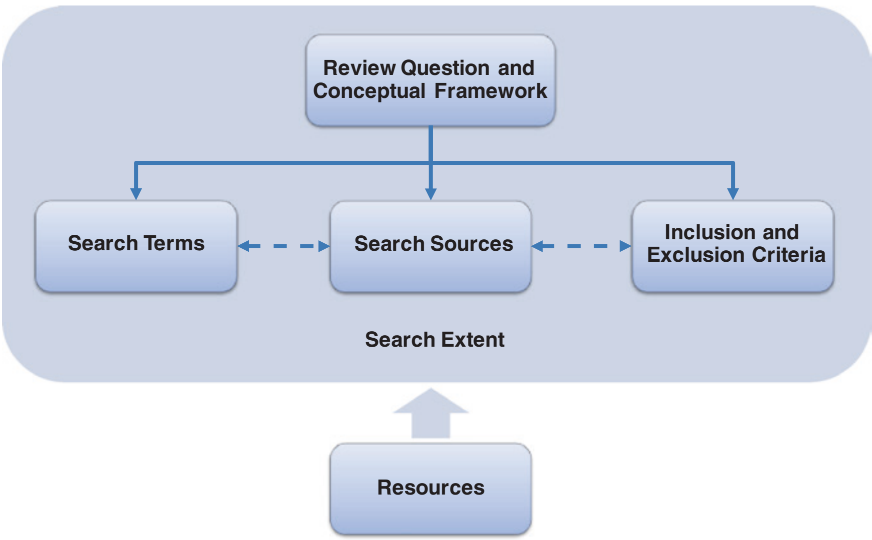

Fig. 7.4 Search strategy. *Source* The authors

Thus, the search strategy should be designed to minimize the chance of biased results, where bias is considered as the tendency to present a partial perspective to the detriment of other perspectives that are potentially equally valid.

A first source of bias stems from the fact that researchers, with regard to quantitative studies, tend to place greater emphasis on studies with statistically significant results. Studies that do not show statistically significant results are often not considered for publication. This problem is known as a reporting bias (Littel at al. 2008).

Another source of bias is publication bias, which can occur when the search is limited to published primary studies. Primary studies are those studies, often empirical, where the knowledge about the object of study was produced (Saunders et al. 2012). The publication bias is defined as the problem arising from the fact that journals and conferences have a greater tendency to accept and publish studies that indicate positive results than studies showing no results or negative results (Kitchenham et al. 2010; Littel et al. 2008).

Furthermore, dissemination bias is related to access to primary studies. Again, studies with positive results tend to be published more quickly, are more often cited, are often available in a larger number of databases and are more likely to have an English version, thus making it more likely for such studies to be included in systematic reviews (Littel et al. 2008).

A systematic review may also be subject to bias due to the process of study selection—what is relevant or not relevant. Hence, it is important that the inclusion and exclusion criteria are defined based on the scope of the review, clearly detailed and strictly followed during the search process (Brunton et al. 2012; Sinha and Montori 2006).

The inclusion and exclusion criteria of studies are initially defined based on the scope of the review, made explicit in the conceptual framework. Some examples of criteria that derive from the scope are population, geographical area and method. However, these criteria may be limited by available resources, such as defining as an exclusion criterion regarding the language of publication of the study.

Concern for the minimization of bias must be present throughout the search strategy, starting with the definition of the search terms. Considering the differences that can be found in the primary studies, it is important that in addition to the main search term, synonyms, antonyms, different spellings and similar expressions are also included. Most search sources allow the use of truncated terms, which may be important in the search. For example, if the desired term is "government", in response to the truncated search term "govern*", the search will return all variants, such as government, to govern and governor. The Boolean operators AND, OR and NOT are used to retrieve specific combinations of terms. The proximity operators NEAR, WITHIN, ADJ specify the relationship between two terms in a field. Table 7.1 summarizes and illustrates the use of the search terms and of the Boolean and proximity operators. It should be emphasized that the search syntax can vary among databases, and therefore it is important to determine the functionalities offered by each one before beginning the search. The search indexes should also be considered, i.e., the position in the document where the terms will be searched. The most common

Table 7.1 Search terms, boolean operators and proximity operators

		Description	Example
Search terms	Exact word	Retrieves the studies that contain the search term in the defined search indexes	*Government*—retrieves the studies that contain the word "government"
	Truncated word	Retrieves the studies that contain variants of the term in the defined search indexes	*Govern**—retrieves the studies that contain the variants "government", "governor" and "to govern", among others
	Exact expression	Retrieves the studies that contain the expression in quotation marks in the defined search indexes	*"Federal government"*—retrieves the studies that contain the exact expression, but not studies that contain only the word "government" or only the word "federal"
Boolean operators	AND	Limits the search to studies that contain the listed words in the defined search indexes, regardless of the order	*Government AND federal*—retrieves the studies that contain these words, regardless of proximity
	OR	Retrieves the studies that contain at least one of the terms in the defined search indexes	*Government OR federal*—retrieves the studies that contain at least one of these words
	NOT	Retrieves the studies that contain the first term but not the second term in the defined search indexes	*Government NOT federal*—retrieves the studies that contain the term "government", but excludes any that also contain the term "federal"
Proximity operators	NEAR	Retrieves the studies that contain the terms located close together in the text. Is more commonly used when using the entire document as the search index	*Government NEAR/6 federal*—retrieves the studies that contain the word "government" and the word "federal" within a distance of 6 words, regardless of the order
	WITHIN	Retrieves the studies that contain the terms closely located in the text and in the order in which the terms are defined. Is more commonly used when using the entire document as search index	*Government WITHIN/6 federal*—retrieves the studies that contain the words "government" and "federal" within a distance of 6 words, in this exact order
	ADJ	Retrieves the studies that contain adjacent terms in the text. Is more commonly used when using the entire document as search index	*Government ADJ federal*—retrieves the studies that contain the words "government" and "federal" adjacently in the text

Source Adapted from Hammerstrøm et al. (2010)

are title, keywords, abstract and the entire document, but not all databases offer all of these possibilities. Another point to be considered in the definition of the search terms is the language. Although most primary studies include an abstract written in English, searching for terms exclusively in this language does not guarantee comprehensive results. If the review team wishes to seek primary studies in a specific language, it is recommended that the search terms also be formulated in this language (Brunton and Thomas 2012; Hammerstrøm et al. 2010; Littel et al. 2008).

Likewise, the definition of search sources is an essential step in formulating an appropriate strategy. Within the available resources, the sources must be comprehensive, thus increasing the chance that all relevant studies are located and consequently minimizing the bias (Sinha and Montori 2006).

The most common search source is the electronic databases to which access is facilitated by database providers, such as ProQuest and EBSCOhost. These databases allow access to a large number of sources, such as journals, theses, dissertations and conference materials (Hammerstrøm et al. 2010). The main databases used for systematic reviews in the management area are shown in Table 7.2.

Although comprehensive, electronic databases should not constitute the only search source in a systematic literature review (Brunton and Thomas 2012; Hammerstrøm et al. 2010; Littel et al. 2008). Relevant primary studies can be found in the so-called *Grey Literature*, also called fugitive literature, defined as "that which is produced on all levels of government, academics, business and industry in print and electronic formats, but which is not controlled by commercial publishers" (Hammerstrøm et al. 2010, p. 20). The proceedings from congresses, seminars and conferences are a good source of *Grey Literature* because more than half of the studies presented there are never published (Hammerstrøm et al. 2010). An additional form for locating *Grey Literature* is through contact with experts in the field, where the "snowball" technique can be used. This technique consists of presenting a previously prepared list of sources to an expert, requesting that they suggest new sources and indicate other experts to be consulted (Littel et al. 2008).

Sometimes, it is necessary to complement the process of identifying primary studies by manual search, which, as the name suggests, involves the manual page-by-page examination of a newspaper, magazine, book or any other printed source. This approach should be considered because not all relevant studies are necessarily included in electronic databases and also because, even when present, they may not contain the relevant search terms in the title or abstract, causing them not to be retrieved in searches (Hammerstrøm et al. 2010).

The use of online search tools, such as Google, Bing and Yahoo!Search, not only provides direct access to primary studies but also allows the identification of organizations and researchers who may constitute new search sources (Brunton and Thomas 2012; Hammerstrøm et al. 2010).

The reference lists of primary studies may be useful for locating other studies, using two similar but distinct procedures. The first, called backward or retrospective, consists of consulting the references of the study; the second, called forward or prospective, refers to searching for new studies that cite the selected document (Brunton and Thomas 2012).

Finally, it is worth considering the importance of studies that have never been published or that are still in progress. Often studies that do not fit the editorial line

Table 7.2 Main databases for research in the management area

	Capes journals (Periódicos Capes) Online library that collects and makes available to educational and research institutions in Brazil the best of international scientific production. It currently has a collection of more than 35,000 full-text journals, 130 reference databases and 11 databases exclusively dedicated to patents, as well as books, encyclopedias and reference works, technical standards, statistics and audiovisual content
	EBSCO Offers over 375 full-text and secondary research databases and more than 420,000 e-books, as well as subscription management services for 355,000 electronic journals and e-journal packages. EBSCO also provides point-of-care decision support tools for healthcare professionals and organizational learning resources for training and development professionals
	Web of Science™ Provides quick access to the main citation databases worldwide. Multidisciplinary database covering over 12,000 of the highest impact journals worldwide, including open-access journals, and over 150,000 conference proceedings, with coverage dating back to 1900
	Scopus I Elsevier With more than 21,000 titles and more than 50 million records, it has smart tools to track, analyze and visualize research. It offers the most comprehensive overview of global research production in science, technology, medicine, social sciences and arts and humanities
	Scielo Database with access to 1,149 journals, 31,894 installments, 467,362 articles and over 10 million citations
	ProQuest Specializing in business, management and related areas, it offers essential content in all its branches. Offers access to over 22,000 full-text Masters and PhD theses selected from the ProQuest Dissertation & Theses database

Source The authors

of journals may not be accepted for publication, but they may still contain relevant information and contribute to the reduction of search bias. For example, studies with negative results have less tendency to be published, but it is essential consider them in a systematic review. Although it is not easy to find them, contacts with

Table 7.3 Protocol for systematic reviews

Search strategy protocol			
Conceptual framework		Concepts that led to conducting the systematic review. May include a summary of the problem situation that is the focus of the review, as well as the known concepts and results	
Context		Context in which the research is being conducted: may include but is not limited to an industry, a sector or a location. For example, small companies in the clothing industry located in the state of Santa Catarina	
Horizon		Time horizon being considered for the review. For example: studies published since 1990	
Theoretical currents		A strategy may or may not limit the theoretical urrents to be searched for. For example, methods of production sequencing based on the theory of constraints	
Languages		Languages to be considered in the searching process	
Review question		The question to be answered by the systematic review. May be the review question itself or derived from it	
Review strategy		() Aggregative	() Configurative
Search criteria		Inclusion criteria	Exclusion criteria
		Criteria that will serve to determine the inclusion or exclusion of primary studies	
Search terms		Terms that will be used to search the databases. Consider not only the terms themselves but also the Boolean and proximity operators	
Search sources			
Databases () Capes journals () EBSCO () Web of science™ () Scopus | Elsevier () Scielo () ProQuest ()	Proceedings () ENEGEP () ()	Internet () Google scholar ()	Others ()

Source The authors

experts and peers can enable their identification, in the same way as described for the *Grey Literature* (Hammerstrøm et al. 2010).

Although there is no single way to structure a search strategy, Table 7.3 presents a suggested protocol oriented towards systematic reviews for academic purposes, which can be adapted to reviews for other purposes.

Once the search strategy is defined, the next step is its operationalization, that is, the search itself of the primary studies, their selection and coding for further evaluation, synthesis and the presentation of the results.

7.2.5 Search, Eligibility and Coding

Once the strategy is defined, the next step in the systematic review is the search, eligibility and coding of the primary studies. The sequence of these activities is depicted in Fig. 7.5.

From the universe of existing studies—which is completely unknown—applying the search terms to different selected sources retrieves a set of studies that must be archived and coded for later use. At this step, one expects to obtain a large number of documents, of which a portion will be truly relevant to the review. The process of identifying which studies are actually relevant is called screening (Brunton et al. 2012).

The screening process requires the inspection of each of the studies found (Adler and Van Doren 1972). The goal is not the complete understanding of the text but a quick read to identify the subject of the study and decide whether it is useful to help answer the review question. First, the titles and abstracts of the studies are read to determine their relevance for the review. Studies that are not considered relevant should be excluded; however, they should still be archived and coded, including information on the reason for their exclusion, explaining what inclusion or exclusion criteria was critical for the decision. Another frequent reason for the

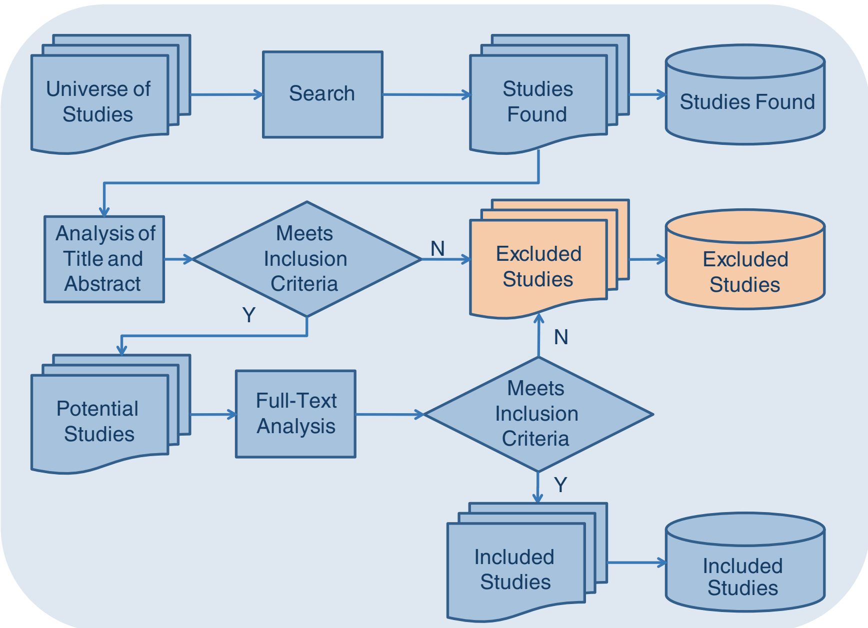

Fig. 7.5 Search process, eligibility and coding. *Source* Adapted from Brunton and Thomas (2012)

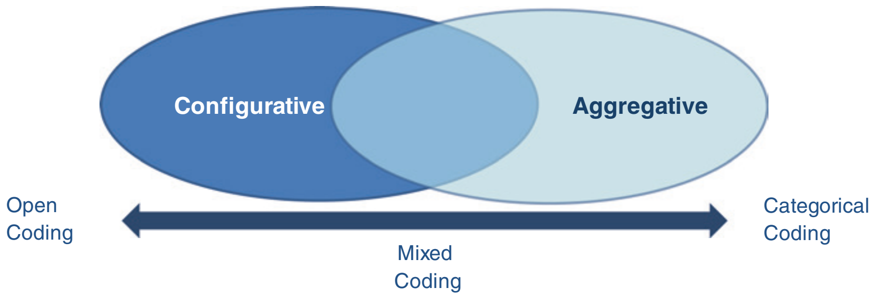

Fig. 7.6 Coding types. *Source* Adapted from Oliver and Sutcliffe (2012)

exclusion of a study is duplication. As many sources are used, it is common for the same study to appear more than once (Brunton and Thomas 2012).

Once potentially relevant studies have been identified, they must be analyzed in depth, i.e., they should be read in their entirety. This reading level, called analytical, seeks a deeper understanding of the study (Adler and Van Doren 1972) to ascertain that it meets the inclusion criteria. Based this analysis, some further studies are likely to be excluded, which should also be archived and coded with the record of the reason for exclusion. Sometimes, a study must be excluded due to inability to access the full text. Likewise, studies that are considered relevant to the review must also be archived and coded for use in the synthesis step (Brunton and Thomas 2012). The coding process of the selected studies (included studies) depends on the review strategy, as illustrated in Fig. 7.6.

In aggregative reviews, where the goal is to test hypotheses, the team is expected to define the major concepts a priori. These concepts are the basis of the coding, although new inclusions can be added as the studies are analyzed. This process is called **categorical coding**. In configurative reviews, where the purpose is to generate or explore theories, few concepts are defined a priori, while most emerge during the analysis of the primary studies; this process is called **open coding**. In this case, the identification of concepts and the creation of codes through the qualitative analysis of data extracted from primary studies are a review product. The occurrence of a **mixed coding** process is also possible when, for example, one wants to explore the differences found in an aggregative review (Oliver and Sutcliffe 2012).

7.2.6 *Quality Assessment*

The confidence in the conclusions obtained by a systematic literature review and hence its usefulness to stakeholders, will be greater the higher the quality and relevance of the review, which must be evaluated considering both the primary studies selected and the review process in a broad manner (Harden and Gough 2012; Smith et al. 2011).

Regarding the primary studies, three dimensions should be evaluated. The first refers to the quality of conducting the study, that is, the assessment of whether the study was conducted within the standards considered appropriate for the topic under study (e.g., sampling and interviews), and whether the findings were based on facts and data. The second and third dimensions seek to assess the relevance of the primary studies to the review, analyzing the adequacy of the primary study to address the review question as well as the focus of the review, e.g., population, method and context (Harden and Gough 2012). Although this assessment can be performed by a single person, it is recommended that it be independently conducted by at least two members of the review team (Harden and Gough 2012; Kitchenham et al. 2010). Each primary study should be assessed by team members, who assign a grade—numerical or categorical, such as high, medium or low—to each of the dimensions. It is worth noting that an appropriate search strategy—e.g., inclusion and exclusion criteria clearly defined, comprehensive and reliable search sources—affects the review quality (Harden and Gough 2012). Table 7.4 provides an example of criteria to be adopted to assess these dimensions; however, adjustments can and should be made to adapt them to each review.

The assessments of the dimensions should then be consolidated to provide a grade for the study being analyzed. This grade can be defined based on an average—in the case of numerical grades—or a rule—in the case of categorical grades. Table 7.5 provides an example of a consolidation rule of categorical grades, in which a study will be considered of low quality if it obtains a low grade in any of the dimensions. Again, it is important to highlight that this rule can be adapted.

In cases where the assessments reach conflicting results, the evaluators should gather in search of a consensus. Studies considered to be of low quality may or may not be included in the review results. Some authors (Brunton et al. 2006; Harden et al. 2009; Kitchenham et al. 2010) adopt as a standard the exclusion of these studies from the results. However, Harden and Gough (2012) suggest three options: (i) include all studies, assigning smaller weights to low-quality studies—applicable to quantitative reviews; (ii) include all studies, describing their quality and relevance so that the readers can draw their own conclusions (Coren et al. 2014); or (iii) perform a sensitivity analysis to assess the effects of including or excluding the low-quality studies.

The quality of the review depends not only on the quality of the selected primary studies but also on the quality of the review process in a broader way, from the correct definition of the review question to the synthesis process and presentation of results. One must assess whether publication, dissemination and selection biases were avoided—that is, if the criteria for inclusion and exclusion were properly selected, if the search sources used covered all relevant studies, and if the quality of the included studies was assessed correctly (Kitchenham et al. 2010). These assessments are made prior to the synthesis of the results, whereas the robustness of the synthesis should be assessed during the process and prior to the dissemination of the results, as discussed in the next section.

Table 7.4 Example of assessment criteria of the dimensions of quality of primary studies

	Dimension		
	Quality of the study performance	Relevance to the review question	Relevance to the review focus
High	The proposed method meets the standards required for the subject under study; the study strictly followed the proposed method; and the results are supported by facts and data	The study precisely addresses the target subject of the systematic review. E.g.: methods of production sequencing in clothing companies	The study was conducted in a similar context to the one defined for the review. E.g.: small businesses in the clothing industry, located in the state of Santa Catarina in the period between 1990 and 2013
Medium	The proposed method has gaps regarding the standards required for the topic under study; or the study fails to show that it followed the proposed method in its entirety; or the results are not fully based on facts and data	The study partially addresses the subject matter of the systematic review. E.g.: methods of production scheduling in clothing companies	The study was conducted in a similar context to the one defined for the review. E.g.: small companies in the *textile* industry, located in the state of Santa Catarina in the period between 1990 and 2013
Low	The proposed method does not comply with the standards required for the subject under study; or the study fails to show that it followed the proposed method; or the results are not based on facts and data	The study only slightly addresses the systematic review subject. E.g.: production management in clothing companies	The study was conducted in a different context from the one defined for the review. E.g.: *medium*-sized company in the *textile* industry in the state of *São Paulo*

Source Adapted from Harden and Gough (2012)

Table 7.5 Example of assessment consolidation

Assessment of dimensions			Study assessment
High	High	High	High
High	High	Medium	Medium
High	Medium	Medium	Medium
Medium	Medium	Medium	Medium
High	High	Low	Low
High	Medium	Low	Low
Medium	Medium	Low	Low
Medium	Low	Low	Low
Low	Low	Low	Low

Source The authors

Table 7.6 Examples of questions to verify the robustness of the review

Question	Description and objective
How reliable are the primary studies included?	Result of the quality assessment process of primary studies. Aims to detect and avoid the inadvertent use of low-quality primary studies
Do the results vary according to the quality of the primary studies used?	Sensitivity analysis of the review results. Aims to assess the impact of the inclusion or exclusion of low-quality studies
Are the results highly dependent on a specific primary study?	Also a sensitivity analysis of the review results. However, in this case, the goal is to verify if the results vary significantly with the inclusion or exclusion of a given study, regardless of its quality
In what context may these results be applicable?	Aims to describe contexts in which the results are applicable. This analysis applies especially to reviews with open questions, where the context was not defined before the search and eligibility of primary studies
How well does the synthesis answer the review question?	Final assessment of the review result. Aims to verify whether the review question can be fully answered. Sometimes, new questions may emerge from the analysis of the results

Source Adapted from Thomas et al. (2012)

7.2.7 Synthesis of the Results

The synthesis process involves combining the results in a connected way to generate new knowledge that did not exist in the original primary studies. In this step, the selected studies should be the target of a syntopic reading, i.e., one that seeks the relationship between texts (Adler and Van Doren 1972). Thus, in addition to

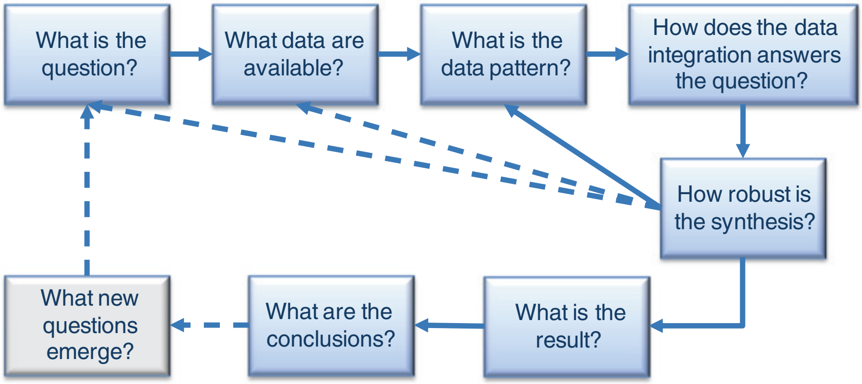

Fig. 7.7 Synthesis process. *Source* Thomas et al. (2012)

a listing or summary of the results found, this step assumes the transformation of data to answer the initial question that led to the review (Thomas et al. 2012).

The synthesis techniques to be used depend strongly on the type of question and consequently on the type of review being conducted. However, the steps depicted in Fig. 7.7 are the most common synthesis methods used. As in the overall review process itself, the synthesis does not follow a linear flow of activities and may require iterations during the process.

The starting point is the analysis and organization of data available from each of the selected primary studies, followed by the identification of the patterns among them. Data integration is the next step, and there are several techniques for use in this step. In addition, this step is where the greatest difference between the synthesis strategies occurs. In aggregative reviews that use quantitative data, meta-analysis and narrative synthesis are the main techniques used. For qualitative reviews, the range of techniques available is much greater (Barnett-Page and Thomas 2009). The robustness of the synthesis must be verified before the definition of results. This verification, which is part of the quality assessment process, can be considered as a sensitivity analysis, i.e., how the results depend on a given study. Once this analysis is performed, the results should be appropriately disclosed so that the findings are understood by their eventual users (Thomas et al. 2012) (Table 7.6).

Next, the main synthesis techniques used in qualitative and quantitative reviews are briefly addressed.

7.2.7.1 Qualitative Techniques

As previously discussed, there are several synthesis techniques that can be used in qualitative systematic reviews, the differences and similarities of which can be analyzed in several dimensions. The main such dimension is the epistemology, which often affects other dimensions, such as the type of the question it proposes to answer, how to assess the primary studies, the iteration level of the process, the similarity among the primary studies and the applicability of the final product (Barnett-Page and Thomas 2009).

Regarding epistemology, the meta-narrative, the critical interpretative synthesis (CIS) and the meta-study can be classified as part of subjective idealism, which considers that there is no single reality independent of the multiple alternatives of human construction. Conversely, the meta-ethnography and grounded theory methods lie in the paradigm of objective idealism, which considers the existence of a shared global understanding. Thematic synthesis, the textual narrative synthesis and synthesis framework are found in alignment with critical realism, which posits that knowledge of reality is mediated by our perceptions and beliefs. Finally, ecological triangulation can be associated with scientific realism, which believes it is possible for knowledge to approach the external "reality". These methods have similarities and differences, and each is applicable to the synthesis of different systematic reviews (Barnett-Page and Thomas 2009). Next, each of the methods will be briefly discussed.

The meta-narrative arises from the view proposed by Thomas Kuhn that knowledge is produced within a given paradigm. Thus, this synthesis method assumes that the main concepts of interest of a given systematic review vary according to the different paradigms prevailing at the time of the selected primary studies were conducted. This method proposes to map the main characteristics, such as the historical route, theoretical foundation, research methods and instruments used, seeking to understand how knowledge has developed, i.e., how previous results have influenced later ones, as well as identifying the strengths and limitations of each paradigm (Barnett-Page and Thomas 2009).

Critical interpretive synthesis is an adaptation of meta-ethnography with elements from grounded theory. More than a synthesis method, it is considered to be a systematic review method as a whole because it involves an iterative approach to refining the review question, to the search and selection of primary studies and to the definition and application of codes and categories. A characteristic of this method is that it evaluates the quality of primary studies more by their relevance than by the method used (Barnett-Page and Thomas 2009).

The meta-study considers three analysis components. Meta-data-analysis is essentially interpretative and seeks to identify the similarities and discrepancies among primary studies in terms of the phenomena described, while the meta-method analyzes the methods their its various aspects, such as sampling, data collection and experimental design. Finally, the meta-theory presupposes the analysis of the theoretical and philosophical assumptions of each of the primary studies, seeking to build a broader view for the generation of the new theory (Barnett-Page and Thomas 2009).

Meta-ethnography was proposed in 1988 by Noblit and Hare as a synthesis process that seeks to combine interpretive reports whose mere integration would be inappropriate. Their first synthesis studies were in the field of education. This method involves three different steps. The first is the translation of the concepts present in the primary studies into more global concepts, which the authors term reciprocal translational analysis (RTA). The next step, called refutational synthesis, requires the exploration and explanation of the contradictions found between primary studies. Finally, the step called *lines-of-argument synthesis* (LOA) involves the construction of an image of the whole, e.g., culture and organization (Barnett-Page and Thomas 2009; Thomas et al. 2012). An advantage of this method is that the interpretations of the review team are explained in such a way that the reader is then able to judge them and decide whether to consider them justifiable or not (Thomas et al. 2012).

The grounded theory developed by Glaser and Strauss has been adapted by several authors as a synthesis process of qualitative reviews. It starts from an inductive approach, in which theory emerges from a simultaneous process of data collection and analysis until theoretical saturation and the generation of a new theory are reached (Barnett-Page and Thomas 2009).

Thematic synthesis combines and adapts approaches from both meta-ethnography and grounded theory. This method was developed to address issues of the suitability, acceptability and effectiveness of interventions. Free codes generated from individual studies are organized into descriptive themes and subsequently interpreted in analytical themes, i.e., as discussed in the synthesis concept, it goes beyond the translation of the primary studies' results to also include their analysis for the establishment of a coherent whole (Barnett-Page and Thomas 2009; Thomas et al. 2012). It is especially suitable for synthesizing the results of multidisciplinary studies, where the review team must consider different paradigms in their analysis (Thomas et al. 2012).

Textual narrative synthesis addresses the creation of more homogeneous groups from a structured report of the characteristics of the primary studies—context, quality and results—and from the comparison of their similarities and differences (Barnett-Page and Thomas 2009).

The synthesis framework proposes a highly structured approach to extracting, organizing and analyzing data based on a conceptual framework built a priori, whose coherence depends strongly on the success of the synthesis process. Thus, this approach is initially deductive, though it allows new topics to be incorporated as they emerge from the primary studies, thereby introducing an inductive element to the synthesis process. The final product can be expressed in graphical form to permit mapping the nature and variety of concepts studied, identifying associations between different subjects and providing explanations for the results from the various primary studies included (Barnett-Page and Thomas 2009; Thomas et al. 2012).

Ecological triangulation aims primarily to answer questions such as what type of intervention causes which type of results for what type of person under what types of conditions. By considering the relationship between behavior, people and environment to be mutually interdependent, this approach maintains that a phenomenon should be studied from different viewpoints because this type of review question can only be answered based on cumulative and multifaceted evidence (Barnett-Page and Thomas 2009).

Dimensions	Methods								
	Meta-narrative	Critical Interpretative Synthesis	Meta-study	Meta-ethnography	Grounded Theory	Thematic Synthesis	Textual Narrative Synthesis	Framework Synthesis	Ecological Triangulation
Epistemology	Subjective Idealism			Objective Idealism		Critical Realism			(Ctrl) c Realism
Type of question	To explore					To respond			
Quality Assessment of Primary Studies	Process less clearly defined; assessment performed less a priori ; greater focus on content quality than method quality					Highly specified process, with well-defined criteria			Method adapted from quantitative research. Excludes low-quality studies
	Assessment of the validity and robustness of the method, sample size and validity of the conclusions	Greater focus on the content than the method		Assesses the relevance of the studies	Assessment of the context, quality and utility				
Similarity of Primary Studies	Heterogeneous	Heterogeneous	Heterogeneous	Homogeneous	Homogeneous	Heterogeneous	Heterogeneous	Heterogeneous	Unclear
Extent of iteration	In all steps	During the search process - unclear if occurs in the other processes	During data collection	During the synthesis processes		During the coding and synthesis processes	Unclear	During the search process	Unclear
Produc	More complex, requiring later interpretation for its application					Directly applicable to the development of policies and design of interventions			

Fig. 7.8 Synthesis techniques for qualitative reviews. *Source* Adapted from Barnett-Page and Thomas (2009)

Figure 7.8 summarizes the different methods and their characteristics regarding the different dimensions. It is possible to identify greater similarities greater among methods that share the same epistemological roots, although they exhibit differences even in such cases.

It is important to note that there are other synthesis techniques in addition to the ones presented. However, their application is more restricted, and therefore they have not been addressed.

7.2.7.2 Quantitative Techniques

Whereas there is a series of synthesis techniques for qualitative reviews, the synthesis technique par excellence for quantitative reviews is meta-analysis, a set of statistical methods used to combine the numerical results of primary studies to produce an overview of the empirical knowledge on a given topic (Littel et al. 2008; Thomas et al. 2012).

An important concept in meta-analysis is the "effect size", a common metric into which the results of the primary studies are converted, which allows the synthesis of the results even when they are expressed in different metrics in the original studies (Littel et al. 2008). Although the term "effect size" is usually used, it is important to note that, because these studies are sample-based, each of the primary studies displays in fact an estimate of the effect associated with an estimate of accuracy—usually the standard deviation. The smaller the standard deviation, the greater the accuracy of the effect size, i.e., the higher the probability that the same effect is found in other samples of the same population. Primary studies that use

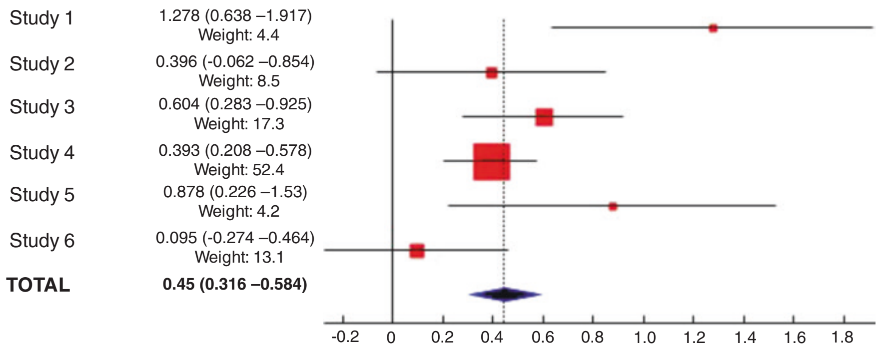

Fig. 7.9 Example of meta-analysis result. *Source* EPPI Centre (2013)

small samples tend to exhibit high standard deviations, while primary studies with larger samples tend to produce results that more closely resemble the results that would be observed in the population of interest as a whole. The estimated accuracy enables creating a confidence interval for each of the effect sizes observed in each primary study (Thomas et al. 2012).

Although not the sole purpose of a meta-analysis, the estimate of the mean effect size based on primary studies is one of the answers sought when this synthesis method is used in a systematic review (Littel et al. 2008). Because the primary studies exhibit different degrees of relevance, the calculation of the mean effect should consider this variation by assigning different weights to the observed effects (Thomas et al. 2012). The assignment of a weight to each primary study is usually performed using the inverse of variance, thus resulting in a smaller contribution of studies with greater variability to the final result (Littel et al. 2008).

The result of a meta-analysis is usually expressed as a forest plot, as shown in Fig. 7.9, where each line represents one study. The square in each line indicates the size of the estimated effect of the primary study, and its size represents the weight assigned to this study, whereas the line extending to each side, represents the confidence interval. The value zero indicates "no effect", and studies whose confidence intervals contain this value are considered statistically non-significant. Some studies may display the value 1, instead of zero, as a reference, depending on the metric used to represent the effect size. The mean effect and its confidence interval are represented by a diamond (Thomas et al. 2012).

An alternative for meta-analysis cannot be used is the topic summarization method, which seeks to quantify the results in a simpler manner, summarizing how many studies reported statistically significant positive results, how many reported statistically significant negative results and how many have yielded inconclusive results, using this information to answer the research question (Thomas et al. 2012).

7.3 Systematic Literature Review and Design Science Research: A Possible and Necessary Connection

This section seeks to assess the connection between design science research and systematic literature review, proposing a generic method of the latter to be used as a research source for the construction of artifacts. As observed, design science research seeks to study, research and investigate artificial objects and, based on the understanding of the problem, to construct and evaluate artifacts that allow the transformation of situations into better or desirable states by changing their conditions (Bayazit 2004; March and Smith 1995; March and Storey 2008). An outstanding characteristic to be highlighted in design science research is the need for its products—the proposed artifacts—to be largely based on pragmatic validity, i.e., there is a foundational requirement that the proposed artifacts generate the desired results, which requires prescriptive knowledge from the researcher (Van Aken and Romme 2009).

Thus, some authors (Alturki et al. 2011; Gregor and Jones, 2007; Van Aken and Romme 2009; Walls et al. 1992) consider the systematic literature review to be an important element in conducting design science research, as a way of seeking the solution to a particular class of problems. The literature review can also enable the identification of design propositions that warrant the continuation of its development—the application of an artifact to a class of problems in a different construction or contingency heuristics—as well as the identification of gaps in the existing literature (Van Aken 2011).

7.3.1 The Systematic Literature Review Method Adapted to Design Science Research

The systematic literature review method previously proposed is generic and meets the needs of *design science research*. However, the goal is to propose a new approach to make it more specific to the research needs. Therefore, special attention is given to the steps of the definition of the review question, research strategy and synthesis of results, as illustrated in Fig. 7.10.

The other steps, while having fewer specific requirements when applied to design science research, must also be present.

7.3.1.1 Review Question

The aim of the systematic literature review during design science research is to build a theoretical and practical framework regarding which artifacts were used for solving of a particular problem or class of problems. Practical, in this case, means

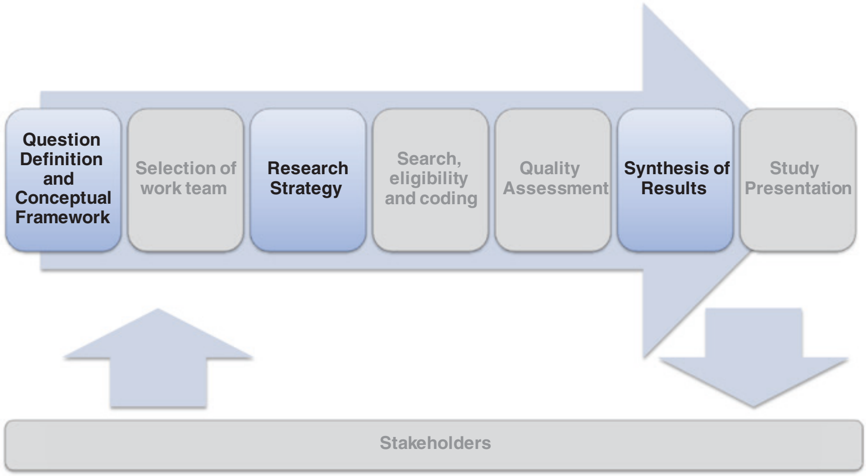

Fig. 7.10 Systematic literature review method. *Source* The authors

that these artifacts must have been tested in the field (Van Aken and Romme 2009). Another aspect that the researcher must consider is the identification of the contingency or construction heuristics present in each of the primary studies researched.

Thus, the generic review question would be as follows: What artifact X has already been used to solve problem Y? Or, for what problems Y or class of problems Z has artifact X been successfully used? (Van Aken and Romme 2009). At the researcher's discretion, the review may be more generic and not specify the construction or contingency heuristics or may be more restrictive in the definition of the context in which the artifact was used.

7.3.1.2 Research Strategy

The search terms to be used in the research are strongly associated with the review question and must contain terms that allow the identification of the problem and its context, if the researcher is interested in limiting the search.

Regarding the definition of search sources, it is worth noting that a design proposition should not only be theoretically grounded but should have been tested in the field (Van Aken and Romme 2009). Hence, the classic sources used in systematic literature reviews—academic databases and journals—may sometimes be insufficient. Van Aken and Romme (2009) comment that for more mature fields of knowledge, a systematic literature review can offer the information that they were tested in the field, but field research must be conducted in new areas of knowledge to obtain the foundations required to formulate a design proposition. Thus, the complementary use of Grey Literature as well as empirical research—conducted with organizations—and expert consultation is strongly recommended as search sources for primary studies that have not been published yet. These sources, as discussed earlier, are also a way to minimize publication bias, i.e., they allow the identification of studies with results that are not positive, which is also of great interest.

Inclusion criteria should be defined based on the review question and the desired characteristics in a study to ground the formulation of a *design proposition*. Thus, one must select those studies that address the problem or class of problems of interest and in which the artifacts proposed have been theoretically grounded and tested in the field with the expected results. Additionally, according to the review question, all primary studies that meet these requirements may be included, or only those studies whose context is aligned with the construction or contingency heuristics selected by the researcher. Primary studies whose artifacts have not been tested or whose results were negative can also be included in the review. However, they should receive special treatment in the synthesis process to allow a correct understanding of their contributions.

The proposed systematic review exhibits both aggregative and configurative characteristics. In the first case, it is important to understand which artifacts have been successfully used more often to solve a given problem, although without the need for a statistical treatment. In turn, the configurative character is due to the exploration of the context in which each primary study was conducted, allowing the researcher to understand the conditions under which an artifact is more likely to generate the expected results. Therefore, the saturation strategy is suggested regarding the extent of the search, aiming to find sufficient primary studies for a coherent answer to the review question (Brunton et al. 2012).

Additionally, because the review displays both configurative and aggregative characteristics, a mixed categorization should be adopted, i.e., some codes must be generated a priori—related to artifacts, problems and heuristics of interest—but there should also be room for new codes to emerge during the search and eligibility of primary studies.

7.3.1.3 Synthesis of Results

Logically, no single synthesis technique can be adopted in this type of review; however, the one best suited due to its characteristics is ecological triangulation. The main objective of this technique is to answer questions such as 'what type of intervention causes what type of results for what type of person under what types of conditions', which in this case can be adapted to 'what type of artifact causes what type of results for what type of problem under which heuristics'.

The synthesis process can begin with a tabulation of the selected primary studies, aiming to form a map of obtained results. A proposal for data organization is shown in Table 7.7.

This type of organization would allow the identification of certain patterns, such as: artifact X1 is suitable as a solution to problem Y2 but only in certain contexts because study 2 showed positive results, but the same performance was not obtained in study 6 using different heuristics; however, artifact X2 was more robust as a solution to problem Y1 because studies 4 and 5 showed positive results in different contexts.

Table 7.7 Proposed data organization for synthesis

Primary study	Problem	Artifact	Construction heuristics	Contingency heuristics	Results	Remarks
1	Y1	X3	H1	H5	Negative	
2	Y2	X1	H4	H7	Positive	
3	Y1	X2	H2	H5	Positive	
4	Y3	X1	H4	H7	Positive	
5	Y1	X2	H3	H6	Positive	
6	Y2	X1	H3	H8	Negative	

Source The authors

Table 7.8 Synthesis matrix

Class of problem	Problems	Artifact	Construction heuristics	Contingency heuristics	Results	Remark	Reference
Z1	Y1	X2	H2	H5	Positive		EP3
			H3	H6	Positive		EP5
		X3	H1	H5	Negative		EP1
	Y2	X1	H4	H7	Positive		EP2
			H3	H8	Negative		EP6
	Y3	X1	H4	H7	Positive		EP4

Source The authors

The objective at the end of the synthesis process is to be able to answer the original review question, that is, which artifact X has been used to solve problem Y or class of problem Z, and in what context? Or for what problems Y or class of problems Z and in what context has artifact X been successfully used? One possibility for the organization of data is the construction of a matrix, as shown in Table 7.8.

The examples shown, for didactic reasons, exhibit results relative to only a few primary studies. In practice, one expects each row of Table 7.8 to correspond to the synthesis of the results of several primary studies. Likewise, it is possible that the problems located in primary studies may be aggregated in different classes of problem.

Although making no claim to be exhaustive, this chapter sought to present the main concepts involved in a systematic literature review and to propose a method for conducting such a review. This chapter also addressed the relevance of the systematic review in conducting research within the design science paradigm, as well as proposing an adaptation of the generic method to the case studied.

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Chapter 8
Prospects

This book aims to revisit the proposals of Herbert Simon in his landmark work *The Sciences of the Artificial*. One of Simon's important contributions is to invite us to rethink our research practices. His intention is not to abandon the research that is being performed, but to expand our conception of science, science's objects and objectives, along with the need to develop knowledge of a prescriptive nature that expresses itself in the design and construction of artifacts.

The development of works that share the ideas and concepts of design science has occurred in a fragmented way. This fragmentation occurs both in terms of research areas (management, information systems, accounting, engineering) and in terms of problems related to design science. Despite this fragmentation, several advances have been achieved due to the effort of renowned researchers worldwide. In this book, we seek to consolidate those contributions, to advance some aspects of those contributions and to create a basis for conducting research using the design science paradigm and research method.

We understand that the concepts and methods presented in this book may be used in several research areas. The key factors for conducting research based on the design science paradigm is to focus on design, construction, and knowledge generated from artifacts. The final result, the artifact itself, makes both an academic and a real contribution. However, the construction process and the knowledge generated during development are essential for both scientific and (primarily) technological advances. Countries with low technological capability must direct a portion of their resources and intellectual efforts in this direction. The motivations for such advances are evident and their discussion is outside the scope of this book.

The research community must rethink their research practices, the relevance of the results of their intellectual efforts and the implications of both for society. The logic of academic productivity must be relativized as the only measure to evaluate the efforts and results of research. It is increasingly necessary to broaden this logic to perceive the actual and concrete implications of the relevance of research. This perspective should be disseminated at all levels of the formative process, especially that of promotion, trying to return to society the trust and in particular, invested resources.

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The design science paradigm and research method propose a path to (i) reduce the distance between theoretical development and its practical implications; (ii) pragmatically reflect on research results; (iii) shorten the distance between academia and organizations, particularly companies; (iv) develop knowledge of artifact design and consequently, technological development; and (v) develop both knowledge and artifacts to provide the best solutions for problems identified in a particular context. In other words, our concern must not be limited to describing, analyzing, explaining and eventually predicting. It also must be concerned with prescribing, designing, and synthesizing. This is most likely the primary challenge of management and engineering research: to simultaneously advance scientific and technological knowledge. An advance that balances advances in these fields is fundamental to building the body of knowledge that future generations will require.

Simon lays the foundation for this development by providing a synthesis. Some of his concepts are key to understanding scientific and technological development. First, he draws a distinction between natural and artificial sciences and acknowledges that artificial sciences are subject to the laws of the natural sciences. However, the artificial sciences comprise a body of knowledge in and of themselves (concepts, methods, techniques, tools) and must not be neglected. Second, he defines of artifact and the necessary components to understand it (outer environment, inner environment, and objective environment). Third, he draws a distinction between substantive rationality and procedural rationality. Fourth, he highlights the importance of satisfactory solutions relative to optimal solutions, an important concept for artifacts' justification and evaluation. Fifth, he points out a hierarchy of complexity that contributes to modularizing and interconnecting artifacts. Sixth, he acknowledges the importance of an adequate representation of the problem to be solved. Finally, he notes the heuristic nature of research.

In light of these conceptual bases, other concepts and methods are necessary to use design science and research. This book intends to show those other concepts and methods. We tried to explore and present a taxonomy of artifacts (constructs, models, methods, instantiations, and design propositions). Throughout the book, we show the historic bases and epistemological positioning of both design science and research. With respect to our methodology, we presented different propositions for performing design science-based research.

In addition to formalization, we seek to advance certain propositions. First, it is important to organize design science research and portray its evolution over time. Second, it is important to historically recover and organize the design science paradigm. Third, we must distinguish the design science paradigm from the design science research method. Fourth, it is important to conceptualize and operationalize the configuration of classes of problems. Classes of problems are a core aspect of the extension/reach of the results of artifacts and of evaluating solutions provided by artifacts. Fifth, we propose a research method grounded on design science research logic and the assumptions of design science. Finally, we advocate a dynamic view of research grounded on design science, with a focus on the central role of contingency and construction heuristics.

There is still much to be developed. The good news is that interest in design science has consistently increased. We fervently hope that this subject does not become a fad, but rather, a field that enables the understanding and development of research in different fields. Since 2009, we have made our best efforts to achieve this goal. Now, we take the liberty of suggesting some lines of research to make design science and design science research even more robust.

We need to advance the understanding and clarifying of the rigor involved in conducting design science research. It is necessary to better understand the research development process that involves researchers in different areas of knowledge in constructing the same artifact. (Would design action research be an alternative?). Another aspect that requires attention is the broadening of the taxonomy of artifacts that follow the principles proposed by Simon. Moreover, that broadening of the taxonomy of artifacts is necessary, so as to better understand instantiations as artifacts.

A deep critical analysis of the research in the field of design science research is needed to determine the field's advances and mistaken practices for the purpose of reflecting on this research method. It is necessary to strongly advance the definition of classes of problems and their importance, so as to justify, evaluate and, especially, determine the reach/extension of artifacts. We also must better understand and formalize the use of well-established research methods (e.g., case studies) conducted based on design science's concepts and assumptions. Finally, we need to better understand how evidence-based management can contribute to the process of constructing artifacts derived from practice (e.g., using the inductive process) and their formalization, understanding, and generalization through design science. These are research concerns that motivate us to look ahead and are an invitation for readers that have been moved by the topic of this book.

We reinforce the need to develop research that is not only rigorous but also relevant. We understand that research must also be directed toward developing artifacts that improve society as a whole. We dedicate our best efforts to achieve that goal. In other words, we try to formalize an epistemological path that enables the development and advancement of scientific and technologic knowledge. Specifically, we are working to establish a path that allows creation of knowledge about the design, execution, and evaluation of the products of artificial science. A path that leads researchers to direct contact with real problems and their consequences, and especially, that guides their intelligence in building solutions. We hope that this constant cycle of learning, guided by the search for solutions, creates a solid body of knowledge today and in the future.