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).

A. Dresch et al., *Design Science Research*, DOI 10.1007/978-3-319-07374-3_4

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

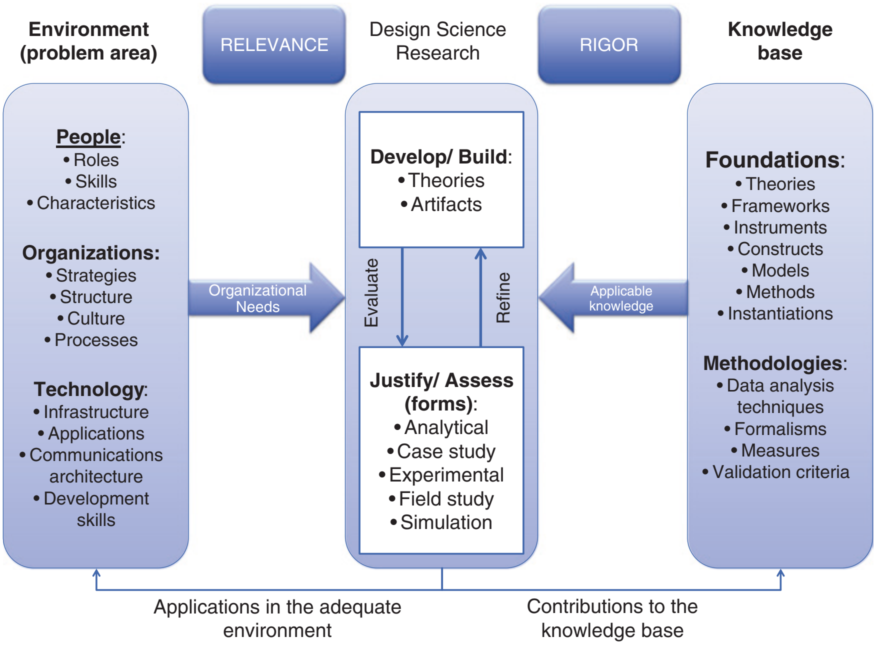


Fig. 4.1 Relevance and rigor in *design science research. Source* Adapted from Hevner et al. (2004)

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

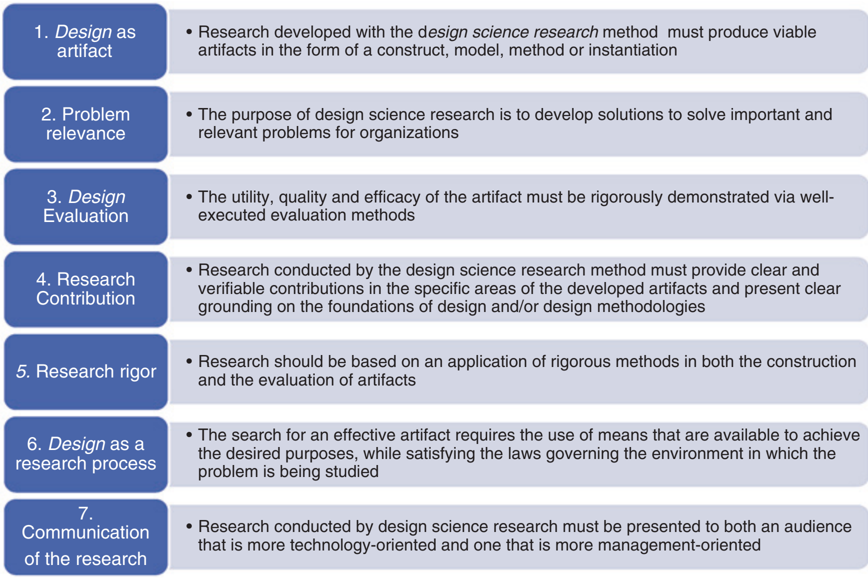


Fig. 4.2 Criteria for conducting *design science research. Source* Based on Hevner et al. (2004, p. 83)

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"

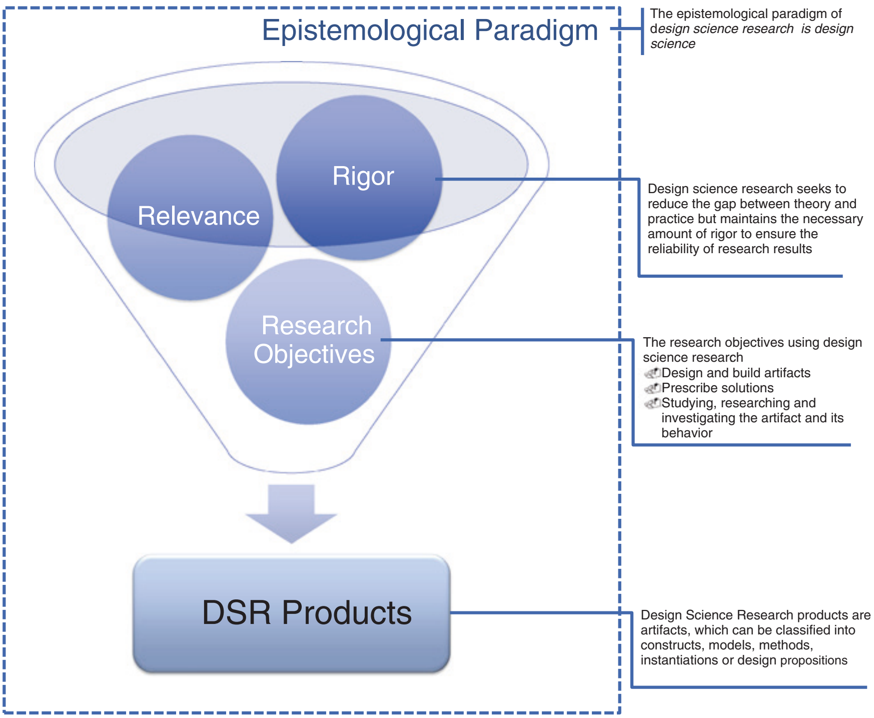


Fig. 4.3 Synthesis of the concepts and foundations of *design science research. Source* The authors

(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*

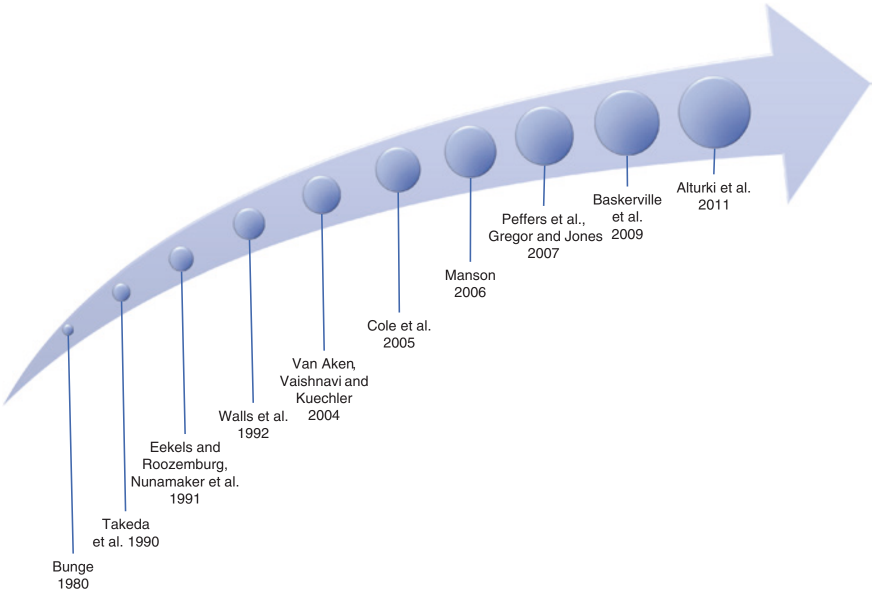


Fig. 4.4 Authors who formalized a method to operationalize *design science*. *Source* The authors

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).

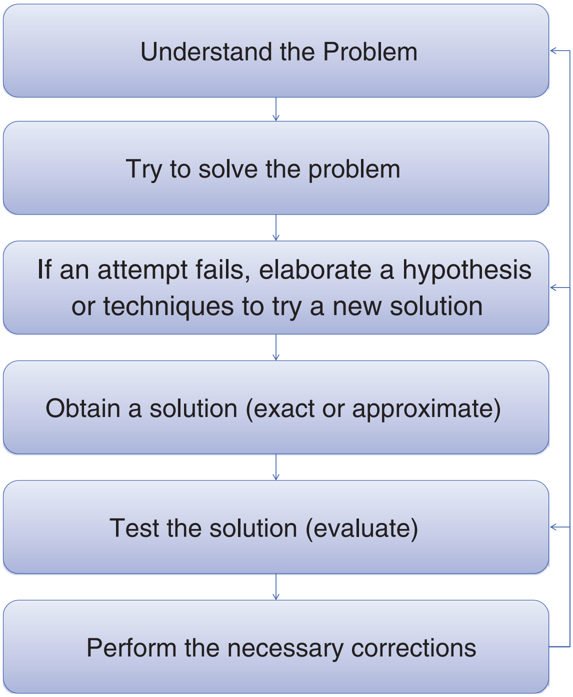


Fig. 4.5 Steps for conducting technological research. *Source* Bunge (1980)

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.

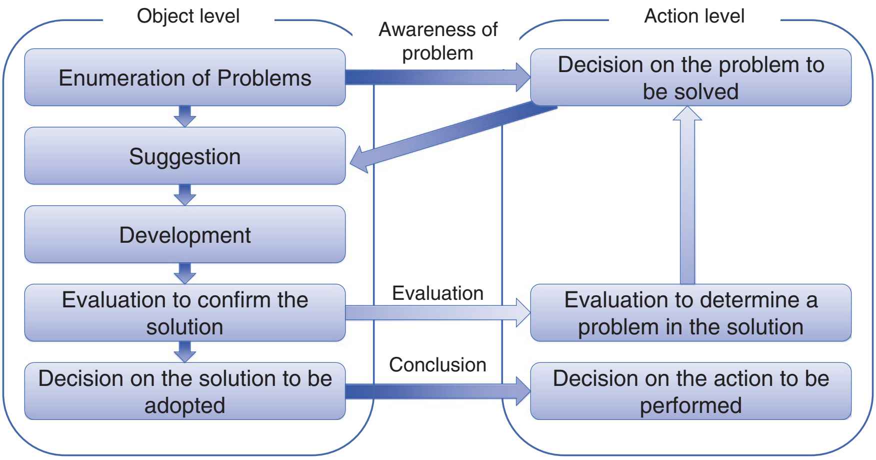


Fig. 4.6 *Design cycle* by Takeda et al. (1990). *Source* Takeda et al. (1990)

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).

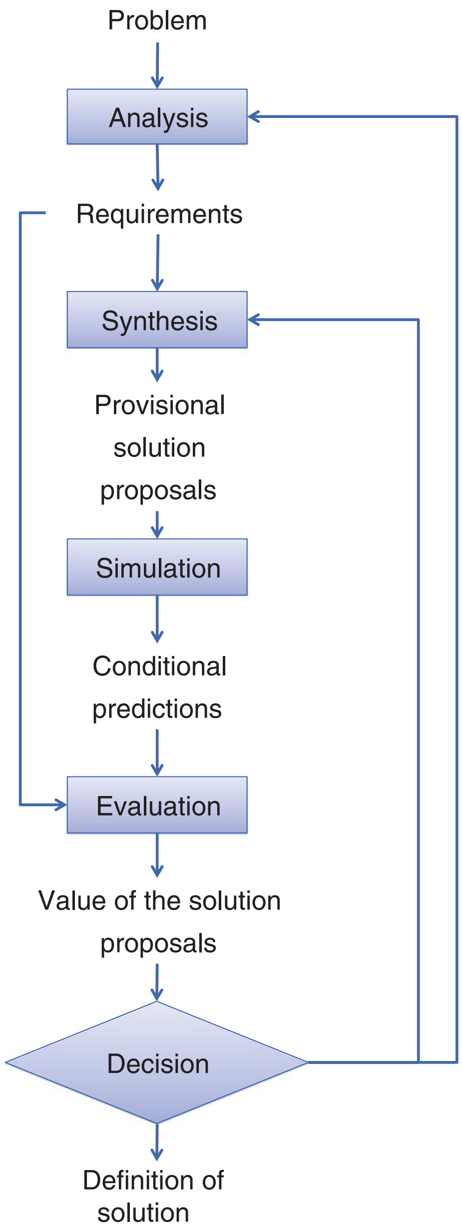
The third step is the *development*. According to Takeda et al. (1990), the researcher develops potential solutions to the problem, for which he/she employs key concepts that are defined in the previous step. The fourth step is the *evaluation,* in which the developed artifact is critically analyzed. 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).

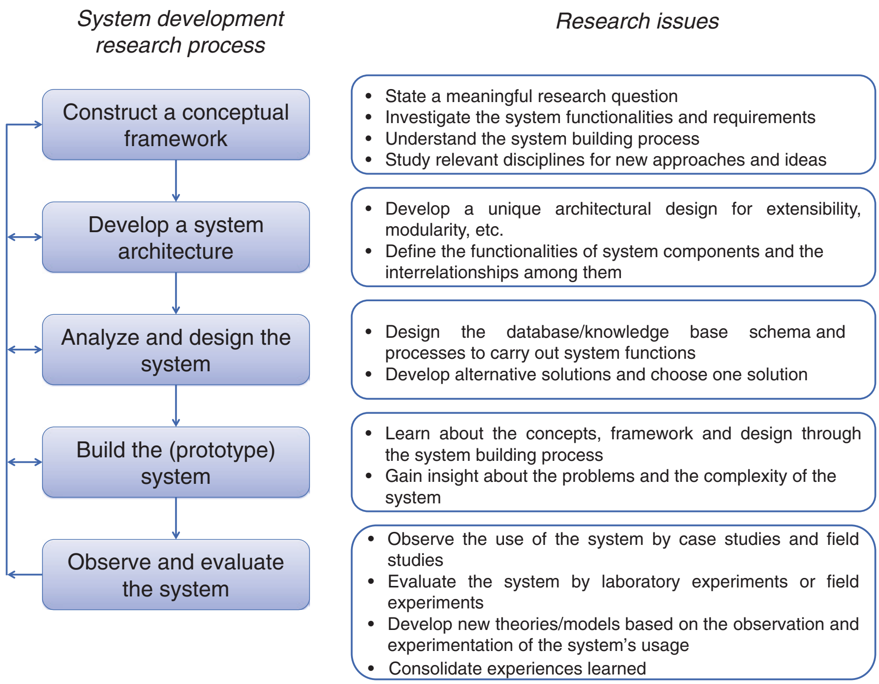


Fig. 4.8 System development research process. *Source* Nunamaker et al. (1991, p. 98)

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

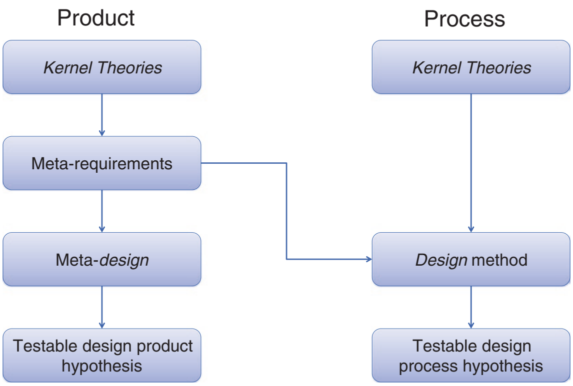


Fig. 4.9 Components for constructing design-based theories in the area of information systems. *Source* Walls et al. (1992, p. 44)

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.

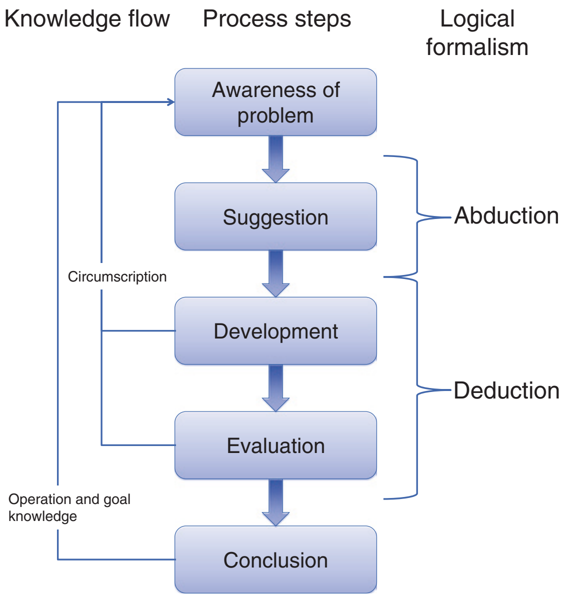


Fig. 4.10 *Design cycle* by Vaishnavi and Kuechler (2011). *Source* Vaishnavi and Kuechler (2011)

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.

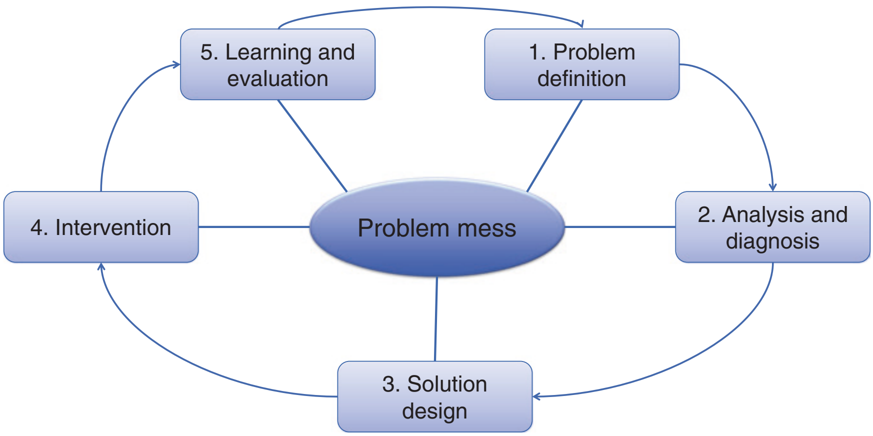


Fig. 4.11 Problem-solving cycle. *Source* van Aken et al. (2012, p. 12)

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.

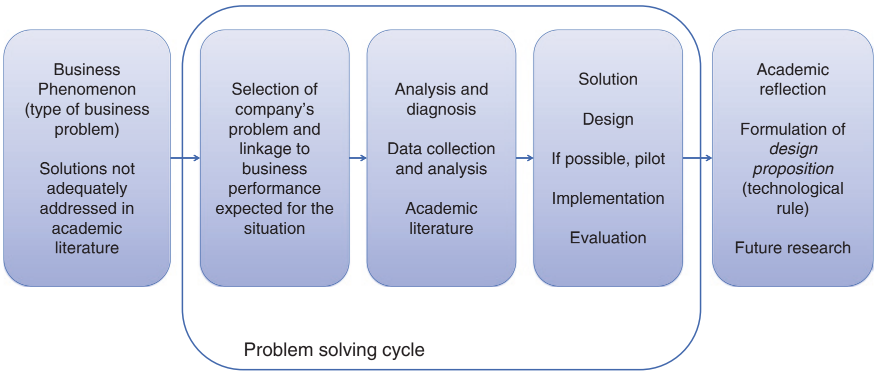


Fig. 4.12 Reflective design. *Source* van Aken et al. (2012)

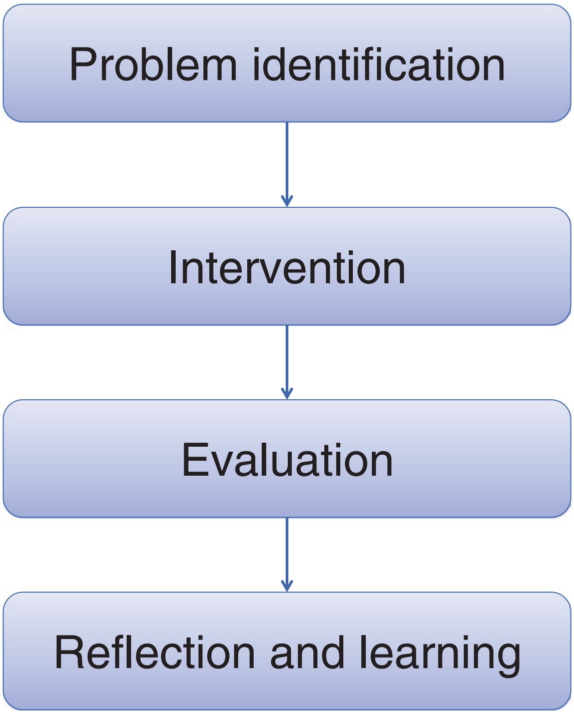


Fig. 4.13 Synthesized research approach by Cole et al. (2005). *Source* Cole et al. (2005)

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).

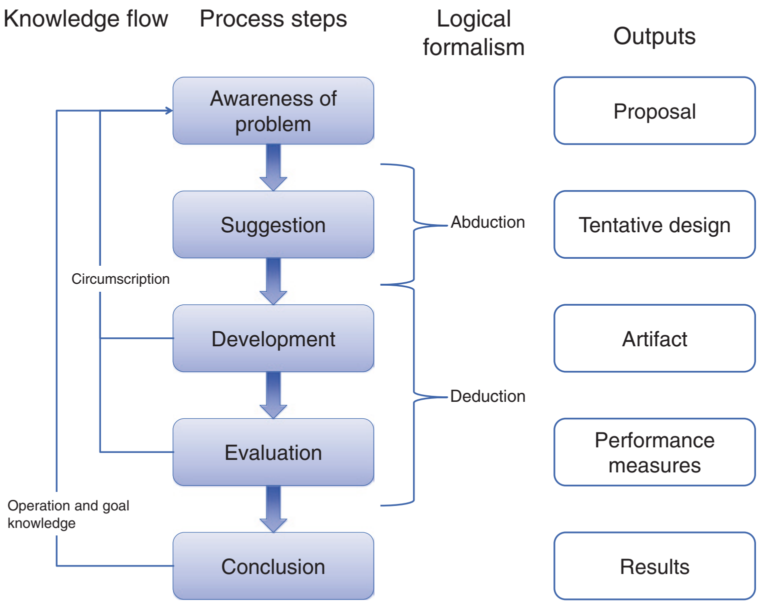


Fig. 4.14 Outputs of *design science research. Source* Manson (2006)

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

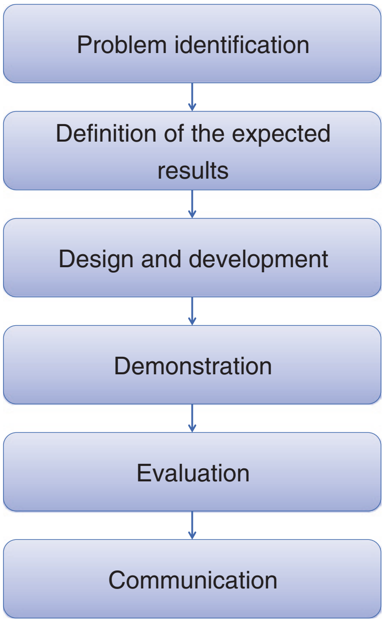


Fig. 4.15 Research method proposed by Peffers et al. (2007). *Source* Peffers et al. (2007)

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

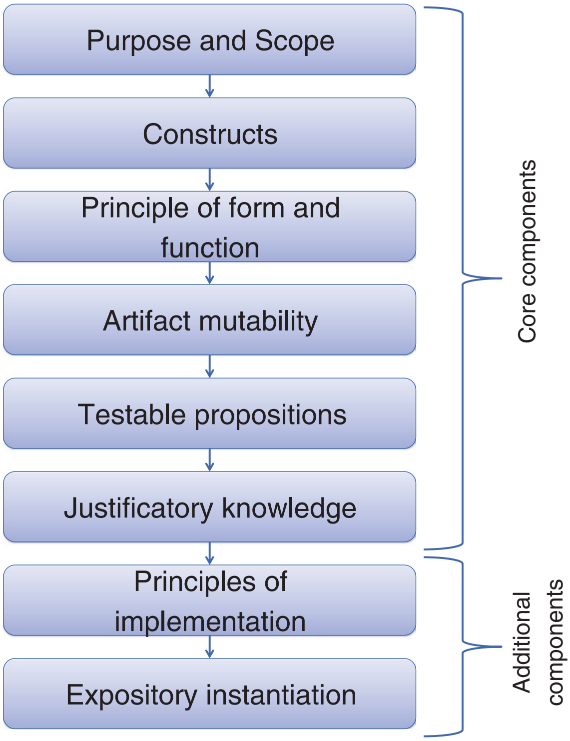


Fig. 4.16 Method proposed by Gregor and Jones (2007). *Source* Adaptation from Gregor and Jones (2007, p. 322)

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).

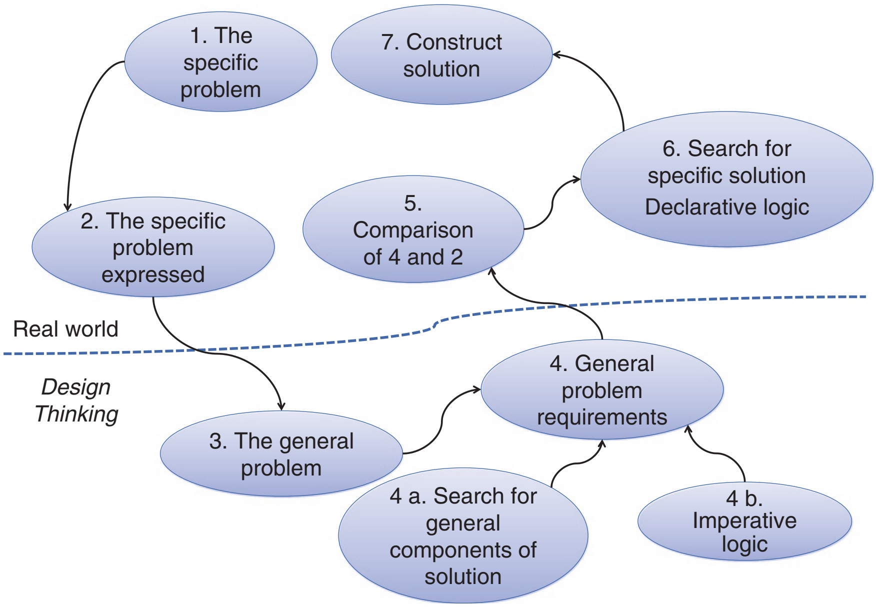


Fig. 4.17 Method proposed by Baskerville et al. (2009). *Source* Baskerville et al. (2009)

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*.

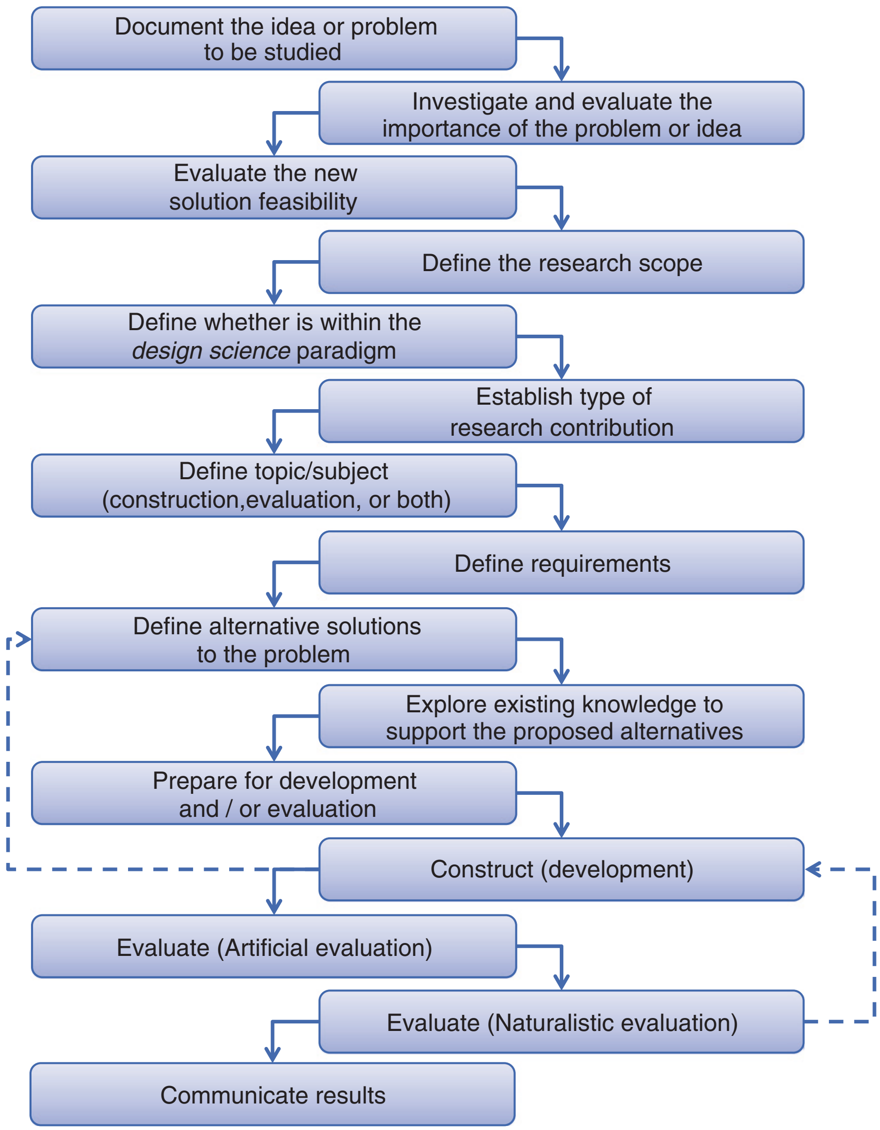


Fig. 4.18 *Design science research cycle* by Alturki et al. (2011). *Source* Based on Alturki et al. (2011)

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)

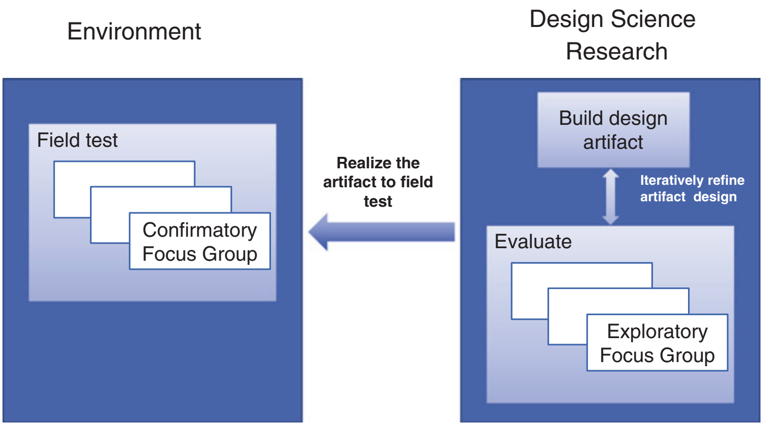


Fig. 4.19 Focus group in *design science research. Source* Tremblay et al. (2010, p. 603)

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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Suggested Reading

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