A Design Science Primer

Paul Johannesson

Erik Perjons

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by Paul Johannesson and Erik Perjons
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Preface

This book is an introduction to design science. It is intended to support both researchers and students in structuring, undertaking and presenting design science work. The level of text is basic and does not presume any prior knowledge of design science.

Chapter 1 provides an overview of design science and outlines its relationships with empirical research. Chapter 2 discusses the various types and forms of knowledge that can be used and produced by design science. Chapter 3 gives a brief overview of common empirical research strategies and methods. Chapter 4 introduces a method that aims at supporting researchers in doing design science as well as presenting design science results. The method consists of five activities, which are described in detail in Chapters 5 to 9. Chapter 10 discusses how to communicate design science results. Chapter 11 compares the proposed design science method with methods for systems development and shows how they can be combined. Finally, Chapter 12 discusses how design science relates to research paradigms, in particular positivism and interpretivism. There is also an appendix that suggests a design science structure for bachelor and master theses. The main text is interspersed with a number of boxes that reflect on various themes in design science; initially the reader may wish to skip these and refer to them later on subsequent reading.

The book offers novel instruments for visualizing design science results, both in the form of process diagrams and through a canvas format.

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The pdf version of the text is designed for eye-friendly viewing on tablets as well as eco-friendly printing on paper, for which it is suggested to print two pages per sheet. Files for download and other documentation can be found at:
http://designscienceprimer.wordpress.com/

Paul Johannesson, pajo@dsv.su.se

Erik Perjons, perjons@dsv.su.se

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1 Introduction

Empirical research aims at describing, explaining and predicting the world. For example, the Linnaean taxonomy describes and classifies the kingdoms of animals and plants into classes, orders, families, genera, and species. Newton's laws are able to explain the motion of planets, the trajectories of missiles and the reasons for tides. Meteorology predicts rainfall, storms and other weather phenomena. The goal of empirical research, at least in the natural sciences, is to faithfully describe and explain the world as it exists regardless of human interests and biases. The world is out there, and can be explained by science so that people have a common understanding of it, irrespective of their backgrounds, traditions and values.

In contrast to empirical research, design research is not content only to describe, explain and predict. It also wants to change the world, to improve it and to create new worlds. Design research does this by developing artefacts that can help people fulfil their needs, overcome their problems, and grasp new opportunities. In this endeavour, design research not only creates novel artefacts but also knowledge about them, their use, and their environment.

This book is about a special strand of design research, called design science, which has its origins in the areas of information systems and IT. Design science in these areas aims to create innovation in the form of ideas, models, methods and systems that support people in developing, using and maintaining IT solutions. This book focuses on design science as applied to information systems and IT, but it also includes examples from and outlooks over other fields of human practice. As design science aims to create artefacts that address problems experienced by people, the rest of this chapter will introduce and relate the notions of people, practices, problems and artefacts.

1.1 People, Practices and Problems

A *practice* is a set of human activities performed regularly and seen as meaningfully related to each other by the people participating in them. An example is the practice of dentists, who engage in cleaning teeth, drilling teeth, pulling out teeth, taking X-rays, and many other activities. When people engage in practices, they will typically need to handle natural as well as man-made objects. For example, dentists and dental nurses will repair teeth and make use of pliers, drills, X-ray machines, etc. Another example of a practice is cooking, where people cut fruit, fry meat, boil vegetables, marinate fish, and so on, while using stoves, refrigerators, pans, graters, and other kitchen utensils.

Practices can be more or less structured or formalized. Some practices take place within organisations, e.g. the production of cars in factories or the management of customer complaints in call centers. Other practices occur in informal settings, for example, kids playing balls in a backyard or people having dinner together. There are also practices in which people can engage as individuals, e.g. brushing their teeth or tying their shoelaces.

When people engage in practices, they may experience problems, practical problems. A *practical problem* is an undesirable state of affairs, or more precisely, a gap between the current state and a desirable state, as perceived by the participants in a practice. The desirable state is seen as better than the current one, because it will allow people to be more successful when engaging in the practice. An example of a practical problem in the practice of dentistry is that, for some people, their dental fillings may fall out after some time. There is a current state in which some dental fillings tend to fall out, and there is a more desirable state in which dental fillings always stay put. The practical problem perceived by dentists is the gap between these two states.

A problem is not always an obstacle to overcome, but can also be a puzzling question or an unexpected circumstance that could provide an opportunity for improvement. Thus, there are two kinds of problems. First, there are problems in which the current state is viewed as truly unsatisfying and the desirable state is seen as neutral, e.g., having a toothache or a flat tire. Secondly, there are problems where the current state is seen as neutral and the desirable state is regarded as a potentially huge and surprising improvement. Often such problems are not perceived until some innovation arises and captures people's imagination, and they realise that their current practice can be improved. An example could be the invention of X-rays, which gave doctors the means to overcome the problem of not being able to view the inside of the human body. Summarising, the term "problem" is used here to denote troublesome situations as well as promising opportunities. (It could be argued that "challenge" and "practical challenge" would be better choices of word than "problem" and "practical problem", but this book sticks with the well-established latter terms).

1.2 Artefacts as Solutions to Problems in Practices

When facing a practical problem, people may react to it in different ways. One option is to adopt a stoic attitude and just accept the problem as a fact of life without trying to do anything about it. The other extreme would be to view the problem as being so serious that the entire practice should be abandoned, or at least part of it. An example could be bloodletting, which was an established practice in medicine for centuries but ceased when evidence mounted regarding its adverse health effects. However, the most common reaction to a practical problem is to try to find some, often partial, solution to it.

In many cases, practical problems can be solved by means of artefacts. An *artefact* is defined here as an object made by humans with the intention to be used for addressing a practical problem. Some artefacts are physical objects, like hammers, cars and hip replacements. Other artefacts take the form of drawings or blueprints, e.g. an architect's plan for a building. Methods and guidelines can also be artefacts, e.g. a method for designing databases. Common to all these artefacts is that they support people when they encounter problems in some practice.

There exists a plethora of artefacts in the IT and information systems area, ranging from algorithms, logic programs and formal systems over software architectures, information models and design guidelines to demonstrators, prototypes and production systems. In the early years of IT, most artefacts were developed for military and business practices. However, in recent times some of the most innovative IT artefacts have been designed for everyday practices, like keeping in touch with friends, sharing and organising photos, or playing games.

The relationships between people, practices, problems and artefacts are summarized in figure 1.1. People engage in practices in which they may perceive problems that can be addressed by means of artefacts. Thus, artefacts do not exist in isolation but are always embedded in a larger context.

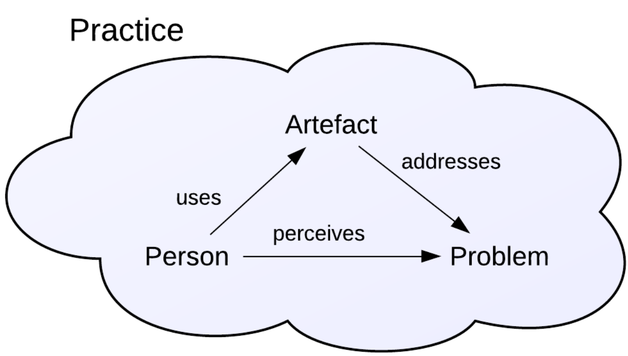

Figure 1.1 People, Practices, Problems and Artefacts

1.3 The Anatomy of Artefacts

Every artefact has an inside, an outside, and an interface between the inside and outside. More precisely, every artefact has an inner construction, is situated in an environment, and offers a function for its intended practice. The *intended practice* is here defined as the practice that holds the practical problem, which the artefact is to address.

The *construction* of an artefact is about its inner workings, the components it consists of, how these are related, and how they interact with each other. An artefact is always constructed from smaller parts that are assembled in such a way that they can interact with each other and produce some behaviour. An example could be a clock constructed from cogwheels, watch-hands, and other mechanical parts. Another example is a truck, which is made of a chassis, an engine, wheels and other parts.

The *environment* of an artefact is about the external surroundings and conditions in which it will operate. The environment of an artefact always includes its intended practice as well as the people and other objects participating in that practice. The environment may also include other practices that are affected by the use of the artefact. Furthermore, the environment may contain various objects that are not related to any specific practice. As an example, the environment of a truck includes the goods transportation practice in which it is used. If the truck passes through areas where kids are playing, the practice of children playing also becomes a part of the truck's environment. Finally, the environment contains the physical surroundings of the truck, including streets and air.

The *function* of an artefact is the intended result of using it in its intended practice, i.e. those benefits the artefact is expected to bring to its users. For example, the function of a clock is to tell the time, the function of a lawn-mover is to cut grass, and the function of a truck is to move goods.

When an artefact is used in a practice, it will have certain *effects* on its environment, i.e. it will change it in intended as well as unintended ways. The intended changes correspond to the function of the artefact. For example, the intended effect of using a truck is that some goods are moved from one place to another, which is the same as the function of the truck. Using an artefact may also have unintended effects, often called *side effects*. These effects may concern not only the intended practice of the artefact but also other practices, sometimes with adverse consequences for them. For example, a truck passing through an area where children play may pose such a safety hazard that the play has to stop. Side effects may also be harmful for other valuable resources even if these are not directly used in any specific practice. Emissions from truck driving pollute the air, which indirectly may harm many practices.

Figure 1.2 illustrates how an artefact is situated in an environment, which may include several practices. The artefact offers its function to the intended practice, but it may have side effects for this as well as other practices. Thus, an artefact may have many *stakeholders*, i.e. people in practices that are affected by it.

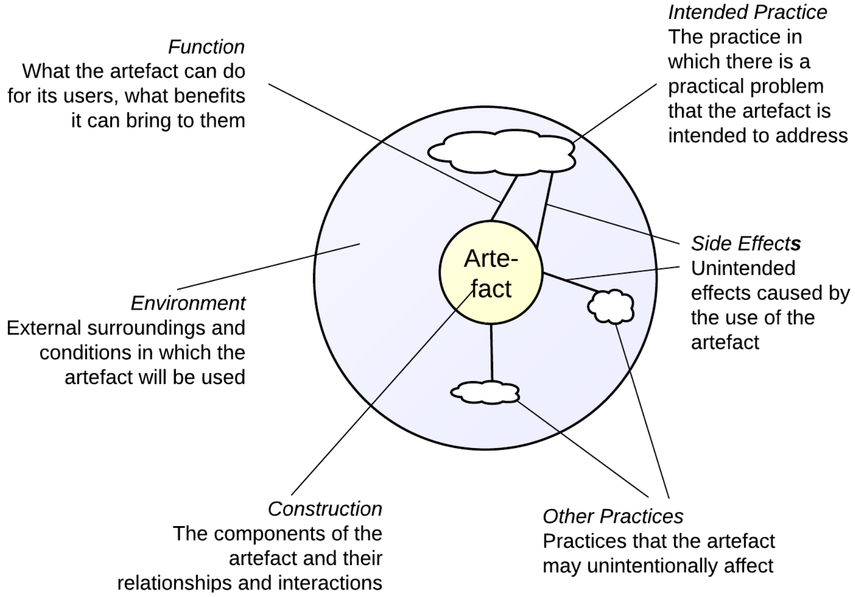

Figure 1.2 Construction, Function and Environment

A common guiding principle in artefact design is to hide the construction of an artefact from its future users and instead focus on its function. A user should not need to care about the internal structure of the artefact but only about its function, i.e. how it can serve the user. Ideally, the user should not even be aware of the construction. An example is a clock, which someone can use without knowing whether it is constructed using mechanical parts or electronic components. In the history of IT, the idea of hiding the internals of an artefact has been applied repeatedly with labels like encapsulation, object-orientation, information hiding, and service oriented architectures.

When designing an artefact, a designer often starts by creating a specification that defines the functional requirements for the artefact, i.e. which functions the artefact should offer. Two requirements for a watch are that it should be usable as a stopwatch and as an alarm clock. Typically, requirements are gathered from and validated by people within the intended practice. The requirements can be expressed as a list of functions of the artefact with no reference to its construction. Instead, the construction can be developed later when the designer has a more complete understanding of the requirements. However, it is also common that function and construction are elaborated in an iterative way.

The distinction between construction, function, and environment is sometimes reflected in the professional roles of designers. For example, in the house construction industry, a construction engineer will focus on the internal structure of buildings, including selection of building materials, layout of plumbing, strength calculations, etc. An architect, on the other hand, will focus on the environment and function of buildings in order to cater for external constraints as well as the needs and requirements of the users. Similarly, in the IT and information systems industry, enterprise architects address business requirements as well as legal, cultural and other environmental factors, while programmers and software engineers focus on the construction of software within the systems to be built.

1.4 Design Science – the Study of Artefacts

Artefacts are studied in different fields of science, including formal sciences, behavioural sciences and social sciences. For example, a study in theoretical computer science (formal science) could determine the complexity properties of a new algorithm for traversing a social graph. A study in psychology (behavioural science) could investigate how photo sharing on social networks influences stress levels. A study in business administration (social science) could examine how the adoption of ERP systems in companies affects their internal communication.

Artefacts are also studied within design science, where they are investigated as solutions to practical problems that people experience in practices. More precisely:

> *Design science* is the scientific study and creation of artefacts as they are developed and used by people with the goal of solving practical problems of general interest

The starting point for a design researcher is that something is not quite right with the world, and it has to be changed. A new artefact should be introduced into the world to make it different, to make it better. The design researcher does not only think and theorize about the existing world. She models, makes and builds in order to create new worlds. She produces both a novel artefact and knowledge about it and its effects on the environment. In particular, she needs to formulate problem statements, determine stakeholder goals and requirements, and evaluate proposed artefacts. In other words, artefacts as well as contextual knowledge are research outcomes for design science.

In this book, design science will be viewed mainly from an IT and information systems perspective. However, the principles underlying design science are applicable to many other areas, see the box on medical science below.

Medical Science and Design Science

Encyclopaedia Britannica defines medicine as "the practice concerned with the maintenance of health and the prevention, alleviation, or cure of disease". Early medical practices incorporated plants, animal parts and minerals as instruments for healing. They were often used in magical rituals overseen by priests or shamans. Medicine thereby became closely related to spiritual systems like animism, shamanism, spiritualism and divination. Today, these relationships have largely been broken, and medical practices are instead supported by medical science.

Medical science is in many ways akin to design science. There is a practice, the medical practice that aims at healing people. There are practical problems that have to do with the effectiveness, safety and cost of engaging in this practice. There are artefacts that address practical problems and support the practice, such as pharmaceutical drugs, medical devices and therapies. A large part of medical science is devoted to studying, in a scientific way, how such artefacts can help solve practical problems in medical practice. Thus, many of the notions and principles behind design science are also relevant for medical science.

1.5 Design and Design Science

Design science may appear highly similar to design, as both focus on the development of artefacts. Both of them also aim at novelty, i.e. they are to produce or investigate original artefacts that differ from existing ones. However, their purposes are different with respect to generalizability and knowledge contribution. While design is a process for developing a working solution to a problem that may be relevant only for a single actor, design science aims at producing and communicating knowledge that is of general interest. Results from design work are sometimes relevant only for a local practice, i.e. a practice in which just one single individual, organization or group engages. In contrast, design science should produce results that are relevant for a global practice, i.e. a community of local practices.

The different purposes of design and design science give rise to three additional requirements on design science work. Firstly, the purpose of creating new knowledge of general interest requires design science projects to make use of rigorous research methods. Secondly, the knowledge produced has to be related to an already existing knowledge base in order to ensure that proposed results are both well founded and original. Thirdly, the new results should be communicated to both practitioners and researchers.

As an example of the specific requirements on design science, consider a project for designing a new electronic health record system. In order to count as design science, the project first has to choose an overall research strategy for investigating the problem situation and eliciting stakeholder requirements. This strategy will include research methods for data generation, e.g. questionnaires for large groups of health care professionals and deep interviews with selected physicians and health care managers. The strategy will also include methods for analysing the generated data. Furthermore, the project has to relate the produced results to existing knowledge within various subareas of health informatics and information systems. This knowledge will include not only established theories and models but also relevant artefacts, in particular other electronic health record systems. Only by relating the project results to existing knowledge, does it become possible to assess their originality and validity. The project must also evaluate the artefact produced using adequate research strategies and methods. Finally, the project has to disseminate its results to both health care professionals and academics through publications in journals and conferences as well as presentations at health care fairs, professional conferences, and other similar events.

Must an artefact in design science aim at changing the real world?

Short answer: Yes

Long answer: In design science, an artefact is an object made by humans with the intention to be used for addressing a practical problem. In other words, some stakeholders must have formulated a goal of the artefact, and this goal has to be related to a practical problem. The stakeholders want to address, or ideally solve, the problem by using the artefact. The stakeholders are not disinterested observers who desire improved knowledge for its own sake, but people engaged in a practice that has encountered a problem. They want to employ the artefact in order to change the world so that the problem is solved or at least mitigated. Thus, theories or descriptive models do not count as design science artefacts, as they aim at explanation and description but not change and problem solving.

Further Reading

One of the earliest and most influential texts on the relationship between design and science is *The Sciences of the Artificial* by Herbert Simon (Simon, 1996). An early paper on design science was written by March and Smith (1995). Another highly influential paper was written by Hevner et al. (2004). Österle et al. (2010) discuss the importance and relevance of design science. Vaishnavi and Kuechler (2004) have designed a web site for design science that includes a large bibliography. The notion of practice is discussed in depth by Cetina et al. (2001). Practice research and its relationships to design science are investigated by Goldkuhl (2012).

2 Knowledge Types and Forms

Scientific research produces different kinds of knowledge and there have been numerous attempts to classify these; one of the earliest being Kant's distinctions between apriori vs. aposteriori and analytic vs. synthetic knowledge. In this chapter, knowledge is classified into six types depending on its contents and uses. The classification builds on a broad view of knowledge as expressed in the following definition from Wikipedia; "Knowledge is a familiarity with someone or something, which can include facts, information, descriptions, or skills acquired through experience or education. It can refer to the theoretical or practical understanding of a subject. It can be implicit (as with practical skill or expertise) or explicit (as with the theoretical understanding of a subject); it can be more or less formal or systematic" (Wikipedia contributors, "Knowledge", 2012).

Another aspect of knowledge is the form in which it can be materialized. This is particularly relevant for design science, as the knowledge it produces is not always explicit but sometimes embedded in artefacts. After having introduced knowledge types in Section 2.1 and knowledge forms in Section 2.2, the chapter concludes with a classification of artefact types.

2.1 Knowledge Types

Definitional Knowledge

Definitional knowledge consists of concepts, constructs, terminologies, definitions, vocabularies, classifications, taxonomies and other kinds of conceptual knowledge. It may be formal and precise, such as the basic concepts of relational database theory, which includes relations, attributes, functional dependencies, and multi-valued dependencies. Definitional knowledge may also include vague and informal concepts like the HCI notions of usability, affordance, and situatedness. Definitional knowledge does not include statements about reality that are claimed to be true. Instead, it is used as a basis for all other types of knowledge in the sense that it provides basic concepts required to express that knowledge. J. G. Bennett (1985) succinctly phrased this as; "We do not know structures, but we know because of structures".

Examples of definitional knowledge:

- A right triangle is a triangle in which one angle is a right angle
- A unicorn is a mythical creature depicted as a white horse with a large, pointed, spiraling horn projecting from its forehead
- A black hole is a region of space from which nothing can escape
- A relation in relational database theory is in third normal form if all of its attributes are dependent on the key, the whole key and nothing but the key

These statements only define certain concepts but do not claim that right triangles, unicorns, black holes, or third normal forms really exist; such claims are made by descriptive knowledge.

Descriptive Knowledge

Descriptive knowledge describes and analyses an existing or past reality. This type of knowledge typically describes, summarises, generalises and classifies observations of phenomena or events. For example, descriptive knowledge can claim that a majority of the ERP users in a company are dissatisfied. In addition, it may describe individual entities and events, for example, that the company Ericsson has invested in a new global ERP system. It may also describe relationships among entities, thereby providing an analysis of these, for example, the modular composition of an ERP system. In contrast to definitional knowledge, descriptive knowledge does include statements that are claimed to be true. In other words, descriptive knowledge claims to describe the world "as is".

Examples of descriptive knowledge:

- The height of the Eiffel tower is 300 meters
- All swans are white
- All large companies in Europe use ERP systems

Descriptive knowledge does not claim to provide explanations or predictions; it only describes.

Explanatory Knowledge

Explanatory knowledge provides answers to how and why questions, explaining how objects behave and why events occur. Explanatory knowledge goes beyond descriptive knowledge, as it not only describes and analyses but also explains in order to offer understanding. Explanations often take the form of cause-effect chains, showing how events and outcomes are causally related to underlying mechanisms and factors. For example, the increased acceptance of Internet banking among the public can partially be explained by improvements in security infrastructures.

High-level explanatory knowledge aims to show how the world can be viewed in a certain way, sometimes with the intent to challenge conventional assumptions and bring about an altered understanding based on novel theoretical perspectives. Some theories that have been used for this purpose are structuration theory, action-network theory, and critical theory. For example, critical theory can be used to explain why information systems introduced for improving productivity, often evolve into instruments for monitoring and control.

Explanatory knowledge on a lower level provides explanations for particular situations, e.g. through case studies, where it explains why and how specific events unfold. For example, the introduction of a reward system in an organization can be a major cause for the employees' acceptance of a new ERP system.

Examples of explanatory knowledge:

- Humans are descended from other animals through a process of natural evolution
- The earthquake in Japan 2011 was a consequence of displacements of tectonic plates
- The failure to introduce social software into the company was caused by its authoritarian organisational culture

Explanatory knowledge only explains events after they have happened and cannot be used for predicting future events.

Predictive Knowledge

Predictive knowledge offers black-box predictions, i.e. it predicts outcomes based on underlying factors but without explaining causal or other relationships between them. The goal of predictive knowledge is accurate prediction, not understanding.

High-level predictive knowledge with a broad generality is not common in the IT and information systems area; one of the few examples is the COCOMO model, (Boehm, 1981), which provides cost estimation for software development. Just as for explanatory knowledge, predictive knowledge can also exist on a lower level where it predicts outcomes in specific situations.

Examples of predictive knowledge:

- Physicians with unwashed hands treating patients may result in diseases
- Heavy exposure to sunlight may result in skin diseases

These examples only predict certain outcomes and do not explain them. Today there are explanations for these predictions but these were not known when this knowledge was discovered.

Explanatory and Predictive Knowledge

Explanatory and predictive knowledge offers both explanations and predictions. It predicts outcomes and explains how these are related, often through causal relationships, to underlying mechanisms and factors. This kind of knowledge is considered the most common in natural science. It is much less common in the IT area, but there are examples such as the Technology Acceptance Model (TAM), (Venkatesh and Davis, 2000), and DeLone and McLean's model of information success, (DeLone and McLean, 2003). Explanatory and predictive knowledge can also be incorporated into more comprehensive theories, like general systems theory and the soft systems approach (Checkland, 1999).

Examples of explanatory and predictive knowledge:

- Microorganisms can survive in dirt and infect people that come into contact with them
- Exposure to the ultraviolet radiation of sunlight may cause a burn of the skin, which may result in skin diseases

These statements both predict possible outcomes and explain them by describing the underlying mechanisms causing them.

Prescriptive Knowledge

Prescriptive knowledge consists of methods and prescriptive models that help solve practical problems. Prescriptive models can be seen as blueprints for developing artefacts, while methods are guidelines and procedures that help people to work in systematic ways when solving problems. Methods often, but not always, prescribe how to construct artefacts.

Methods and prescriptive models can be viewed as comprising two parts. The first is the model or method itself, and the second is a statement about some desirable effect of using the model or method. This statement is not a subjective judgement that some effect is desirable in an absolute way. Instead, it is a predictive statement implying that if a method or prescriptive model is used in a certain practice, this will contribute to effects desired by some stakeholders. In this sense, prescription can be seen as a special case of prediction.

Typical examples of methods are systems and software development methods like RUP (Kroll and Kruchten, 2003), or agile methods like XP and SCRUM (Cohn, 2009). Examples of prescriptive models are conceptual reference models like SCOR (Bolstorff and Rosenbaum, 2007), or architectural models like OSI (Day and Zimmerman, 1983).

Examples of prescriptive knowledge:

- Wash your hands before going to surgery!
- Apply sun lotion before sun bathing!

> Is there a difference between models in social science and design science?
>
> *Short answer:* Yes
>
> *Long answer:* Social science produces models that describe and predict phenomena and behaviour in a domain, i.e. descriptive and predictive models. In contrast, design science produces models that can be used as blueprints for developing artefacts, i.e. prescriptive models.

2.2 Knowledge Forms

While knowledge types describe how knowledge can be used, knowledge forms specify how it can be materialized, i.e. where it exists and in which shape. Knowledge forms are important for design science work, as it creates not only knowledge explicitly codified in documents but also embedded in artefacts. The following subsections will introduce the three main knowledge forms and their roles in design science.

Explicit Knowledge

Explicit knowledge is articulated, expressed and recorded in media such as text, numbers, codes, formulas, musical notations, and video tracks. Typical containers of explicit knowledge are encyclopaedias, textbooks, and manuals. A main strength of explicit knowledge is that it can be easily transferred between individuals, as it is stored in media that can be moved and decoded in a convenient way. However, not all knowledge can be articulated in an explicit way, e.g. practical skills, intuitions and experiences. Reading a manual on how to ride a bicycle will not help much in learning that skill.

Embodied Knowledge

Embodied knowledge is situated in the minds of people and is typically difficult to formulate in an explicit way. For example, although almost everyone is able to read facial expressions correctly and effortlessly, no one would be able to articulate fully how this is done. Other examples of embodied knowledge are tying a shoelace, speaking English, or using a video recorder.

Sometimes, efforts are made to transform embodied knowledge into explicit knowledge, for example, by companies who want to retain the knowledge of employees who are going to quit. The goal of such a transformation is that people without expert background should be able to replicate the performance of those who possess relevant, embodied knowledge. However, the person using knowledge in an explicit form will typically lack the ability of the skilled practitioner to innovate and adapt to new circumstances. In this sense, the extracted, explicit knowledge is inferior to the embodied knowledge.

Embedded Knowledge

Embedded knowledge resides not in humans but in entities, like physical objects, processes, routines, or structures. As an example, consider a bread maker, i.e. a home appliance for making bread. When loaded with the right ingredients, such a machine is able to produce a loaf of bread by mixing those ingredients, kneading the resulting dough, and then baking it; someone studying how the machine works can learn about bread making. Thus, the machine can be seen as embedding the prescriptive knowledge of how to make bread; it embeds a recipe, a method. Furthermore, by studying the construction of the machine, someone can learn about the architecture of bread making machines in general. It may even be possible to create a (prescriptive) model for building new bread makers. In this way, the machine also embeds a model.

In general, an object can embed both models and methods. Just as for embodied knowledge, such embedded models and methods can sometimes be made explicit. However, this requires a transformation that typically loses some of the embedded knowledge, i.e. the extracted models or methods are poorer than the ones embedded in the object. (The process of discovering the principles behind an artefact through an analysis of its functionality and construction is commonly known as *reverse engineering*, which has a long tradition within military as well as industrial practices.)

2.3 Knowledge in Craft and Science

In traditional crafts, representing and transferring design knowledge is most commonly done by embedding it within objects. This is not due to laziness of the designer, but because objects are able to embed design knowledge with all its richness and nuance. An apprentice carefully studying an artefact designed by her master will gain a deep and intuitive understanding of the principles used in creating it. In this way, the design knowledge embodied in the master becomes embodied in the apprentice, using the artefact with its embedded knowledge as an intermediary.

Representing and transferring knowledge by embedding it in artefacts can offer substantial benefits with respect to richness and intuition, but there are also several disadvantages. First, acquiring knowledge by directly studying artefacts can be time-consuming. This is evidenced by the many years it typically takes a craft apprentice to become a master. Secondly, the knowledge someone actually acquires by studying an artefact is highly dependent on that person's background, interests and capabilities. Some people may learn effectively from examining an artefact, while others may fail to do so. Thirdly, it is difficult to analyse, criticize and evaluate knowledge embedded in an object. Analysis, criticism and evaluation are usually more effective and meaningful when the knowledge is explicit.

One of the main purposes of design science is to support designers and researchers in making design knowledge explicit, thereby moving design from craft to science. Design science offers this support by clarifying principles behind design and by providing methods for creating artefacts as well as explicit knowledge about them. However, it should be acknowledged that not all the knowledge embedded in an artefact can be made explicit and, therefore, the artefact itself is a vital result of any design science project. As stated by Robin Mathew, "Design is where science and art break even".

2.4 Artefact Types

Based on the knowledge types and forms introduced, it is possible to distinguish between different artefact types. Within the IT area, it has become common to identify four such types: constructs, models, methods, and instantiations.

Constructs are terms, notations, definitions, and concepts that are needed for formulating problems and their possible solutions. Constructs do not make any statements about the world, but they make it possible to speak about it, so it can be understood and changed. Thus, constructs are definitional knowledge. Some examples are the concepts of class in UML, method in Java, functional dependency in relational database theory, and affordance in HCI. Constructs are the smallest conceptual atoms with which to understand and communicate about various phenomena.

Models are used to depict or represent other objects. A model can represent an existing situation, which can be used for describing and analyzing problem situations. Such a *descriptive model* may work as a pedagogical tool for representing a current situation and explaining why it is challenging. However, models can also be used to describe potential solutions to practical problems, e.g. a drawing for a new type of vehicle or a proposal for an architecture of a mobile operating system. Such *prescriptive models* work as descriptions of possible future solutions and help to build artefacts that can solve practical problems. There are also *predictive models* that can be used to forecast the behavior of objects and systems. Thus, models can express descriptive as well as predictive and prescriptive knowledge. In design science, the focus is on prescriptive models. Typical examples are business process models, systems architectures, domain ontologies, and user models.

Is a model a theory?

Short answer: No

Long answer: A theory aims to explain by showing how phenomena and behaviour in a domain are related to each other, typically through cause and effect relationships. In contrast, a model aims at representation, as it represents all or part of a system. It is possible to distinguish between three kinds of models: descriptive, predictive, and prescriptive (or normative) models. A descriptive model describes some existing system but without offering any explanations. A predictive model allows forecasts of events, e.g. weather forecasts. A prescriptive model, e.g. a drawing for a new building, can be used for guiding actions, thereby helping people to fulfil their goals.

Caveat: Even if models are not theories in themselves, descriptive and predictive models can still be a part of theories. For example, a conceptual model in the context of agency theory could include and relate constructs like principal, agent, risk, goal, contract, and monitoring (Eisenhardt, 1989). Such a model provides a conceptual basis for agency theory but does not count as a theory in itself. To do so, it has to be complemented with explanatory propositions like “As the principal and the agent have different goals, the agent does not always act in the interest of the principal” or predictive statements like “Monitoring may improve the efficacy of behaviour-based contracts”. Simplifying, theory = descriptive model + explanations + predictions.

Methods express prescriptive knowledge by defining guidelines and processes for how to solve problems and achieve goals. In particular, they can prescribe how to create artefacts. Methods can be highly formalized like algorithms, but they can also be informal such as rules of thumb or best practices. Some examples are methods for database design, change management initiatives, or web service development.

Instantiations are working systems that can be used in a practice. Instantiations can always embed knowledge, e.g. a database can embed a database model. Some examples of instantiations are a Java program realising a search algorithm, a database for electronic medical records, or a new planet in the computer game Entropia.

What do instantiations instantiate?

Short answer: A model of a working system

Long answer: In this book, an instantiation has been defined as a working system that can be used in a practice. However, the term “instantiation”, which has become well established in the design science community, indicates that the system should be an instantiation of some other artefact. So, the question arises - what kind of artefact is instantiated? The candidates are the three types of abstract design science artefacts: construct, model and method. Constructs are out, because instantiating a construct will give rise to something that is much too small to be a working system. Models, such as blueprints and architectures can clearly be the basis for a working system, so models can be instantiated. The remaining question is whether methods can also be instantiated. Applying a method for developing a system should obviously result in a working system. However, this system is not an instantiation of the method. Rather, the instantiation of the method consists of the actual actions and events that occurred during the system's development. Thus, a method instantiation would not count as an instantiation when the latter is defined as a working system.

It could now be argued that our definition of instantiation is too narrow and that method applications should also be included in it. One argument in favour of this view is that methods are so complex and situation dependent that they cannot be fully specified in words. Instead, some of the knowledge has to be embedded in particular method applications. Such knowledge can then be communicated, for example, through video recordings. Although in principle this argument has much merit, it is in practice quite difficult to transfer knowledge through method applications, because in the IT area, these typically span over extended periods of time. Watching videos of many hours of meetings and discussions is not an attractive option. Thus, our definition of instantiations as working systems is not very restrictive in practice. However, it could be speculated that in other areas, such as physiotherapy, method applications would be useful design artefacts. Watching a one-minute video on an innovative physiotherapy exercise could be a highly effective instrument for knowledge transfer.

Must an instantiation always be an IT system?

Short answer: No

Long answer: An instantiation has been defined as a working system that can be used in practice. Clearly, such a system can be an IT system, like a hardware device, a computer program, or a combination thereof. However, there is no reason to make a restriction to only IT systems. An instantiation could also include other components, such as an IT system in an organisation together with new work processes and business rules. Another example could be a digital art installation that consists of sculptures, people and IT artefacts. In general, an instantiation can contain any physical, informational, biological or social components as long as they comprise a working system.

Caveat: Although an instantiation can be more than IT, much work on instantiations within design science has actually focused on IT systems. One probable reason for this is that it is complex to construct and evaluate artefacts that contain not only IT but also physical, human or social components.

Further Reading

The knowledge types introduced in this paper builds on the work performed by Gregor (2006). Knowledge forms are discussed by Madhavan and Grover (1998). The artefact types of design science are introduced and described by March and Smith (1995) and Hevner et al. (2004).

3 Research Strategies and Methods

The purpose of research is to create reliable and useful knowledge based on empirical evidence as well as logical arguments. The evidence and the arguments need to be presented in a clear way to other researchers, so that they can review them and determine whether they hold up to the standards of academic research. In order to support researchers in creating, structuring and presenting their results, many scientific communities have evolved and established a number of research strategies and methods. This chapter offers an overview of a number of well-established research strategies and methods for empirical research, particularly within the social sciences. These strategies and methods are useful also when doing design science, in particular when investigating practical problems, defining requirements and evaluating artefacts.

3.1 Data Generation and Analysis Methods

An early activity in any empirical research study is to collect data about the phenomenon under investigation. For this purpose, *data generation methods* are used. The data collected may be numeric (often called quantitative data), e.g., number of lines of code, number of software installations, and the visitor frequency of a web site. Other kinds of data include text, sound, images, video, etc. (often called qualitative data). Five of the most widely used data generation methods are: interviews, group discussions, questionnaires, observation studies, and document studies.

Interviews

An interview is a communication session between a researcher and a respondent, where the researcher controls the agenda by asking questions of the respondent. An interview can be structured meaning that it strictly follows a predefined protocol. Alternatively, it can be semi-structured or unstructured, providing opportunities for digressing from a protocol and allowing the respondent to take initiatives. An example of an interview is a researcher evaluating a new MMORPG by asking a player of the game about her view of its graphical interface.

Group discussions

A group discussion is a communication session in which a researcher and a group of respondents interact under the guidance of the researcher and the participants influence each other in order to generate information. An example of a group discussion is a group of business intelligence experts together with a researcher, defining major steps in a method for identifying key performance indicators for measuring organisational performance.

Questionnaires

A questionnaire is a written document consisting of questions distributed to a number of respondents. A questionnaire can include questions with predefined answers, as well as open questions where the respondent can answer more freely. An example of a questionnaire is different stakeholders in an organisation filling in a form on how they prioritise among a number of requirements for a planned CRM system.

Observation studies

In an observation study, objects are observed in their natural environments. The researcher often tries to be as invisible as possible in order not to interfere with the natural dynamics of the situation under investigation. An example of an observation study is a researcher gathering information on the learnability of a mobile app by actually observing people using it.

Document studies

A document study is a special kind of observation study where existing documents are examined, including policy documents, user manuals, video recordings, system specifications, system logs and websites. An example of a document study is a researcher identifying problems experienced during a systems development project by reading relevant meeting notes.

When data have been generated, they need to be analysed. For this purpose, there exist both quantitative and qualitative data analysis methods. *Quantitative data analysis* focuses on numeric (quantitative) data and uses mathematical approaches, in particular statistical ones, in order to investigate, interpret and structure data. *Qualitative data analysis* is about interpreting data of any form (both qualitative and quantitative) by discovering themes and patterns in them, thereby using the personal skills and understanding of the researcher who undertakes the analysis. Examples of qualitative analysis methods are content analysis and narrative analysis.

3.2 Research Strategies

Data generation and analysis methods are never used in isolation but always in the context of a research strategy, i.e. an overall approach to answering a research question. In addition to data generation and analysis methods, a research strategy includes the general set-up of the context in which the research is undertaken. Some well-established research strategies are surveys, experiments, case studies, action research, grounded theory and ethnography.

Surveys

A survey starts by generating data from a large group of objects (people, organisations, systems, etc.) often through use of questionnaires or document studies. The data are then analysed, typically by a quantitative method, in order to find generalisations. An example of a survey is an investigation aiming at identifying problems that public organisations experience when introducing workflow systems. The main data generation method of the survey is questionnaires distributed among a sample of managers and users of workflow systems.

Experiments

In an experiment, a researcher creates an artificial environment that will make it possible to isolate and study a small number of objects, thereby preventing other objects from influencing those under investigation. The researcher will then observe (a data generation method) the behaviour and relationships of the objects in the environment and analyse the generated data (using a data analysis method), often with the purpose of establishing cause and effect relationships. An example of an experiment is a researcher investigating causes of failures in an embedded system by sending the system several commands in parallel.

Case studies

A case study investigates in detail one specific case of the general phenomenon under investigation, e.g. one organisation, one systems development project, or one mobile application. The purpose of a case study is to paint a rich picture of a single object or situation as a basis for obtaining a deep and comprehensive understanding of some general phenomenon. An example of a case study is a researcher studying organisational change as a result of introducing a business process system in an organisation. To understand the change, the researcher follows the organization for a long period of time. She makes use of observations, document studies (analysing system logs), and interviews. Thereby, she can identify discrepancies between the actual execution of business processes (using analyses of the system logs and observations) and user perceptions of the execution.

Action research

In action research, a researcher introduces some change into a real environment. For example, a researcher may actively introduce a new method or system in an organization together with its employees. She then studies and reflects on the effects of this change using any data generation and data analysis methods. An example of action research is a researcher introducing a method for identifying innovative e-services in an organisation. The researcher and the employees of the organization can apply the method together, and the researcher will collect data about the application. She can also perform an evaluation of the method, for example, by interviewing the employees.

Grounded theory

In grounded theory, a researcher generates theory or hypotheses from data. She gathers data from a practice and identifies patterns or structures in the collected data, which will become the base for creating the theory or hypotheses. A main thrust in grounded theory is that the researcher should try to avoid applying her pre-understanding or theoretical knowledge about the data. Instead, the data should "speak for itself" to the researcher and be the sole, or at least primary, basis for creating the theory.

Ethnography

In ethnographic studies, the purpose is to understand the culture and perspectives of some group of people, e.g., systems administrators in a large company. The researcher is not a detached observer but tries to become a part of the studied group by participating in their daily activities. Thereby, she gains a deep and comprehensive understanding of how some groups view their practice. An example of an ethnographic study is a researcher working as an employee during a time period in order to understand why a group of employees refrain from using a decision support system.

Can social science be used when doing design science?

Short answer: Yes

Long answer: Social science offers models and theories as well as research strategies and methods, which can be used when doing design science. Social science models and theories are often key components of the knowledge base used when developing artefacts. As an example, agency theory is essential when developing auditing systems. Furthermore, research strategies and methods in social science are applicable in all the activities of the design science method. For example, interviews and observation can be used for requirements definition, and both experiments and case studies can be applied for evaluation.

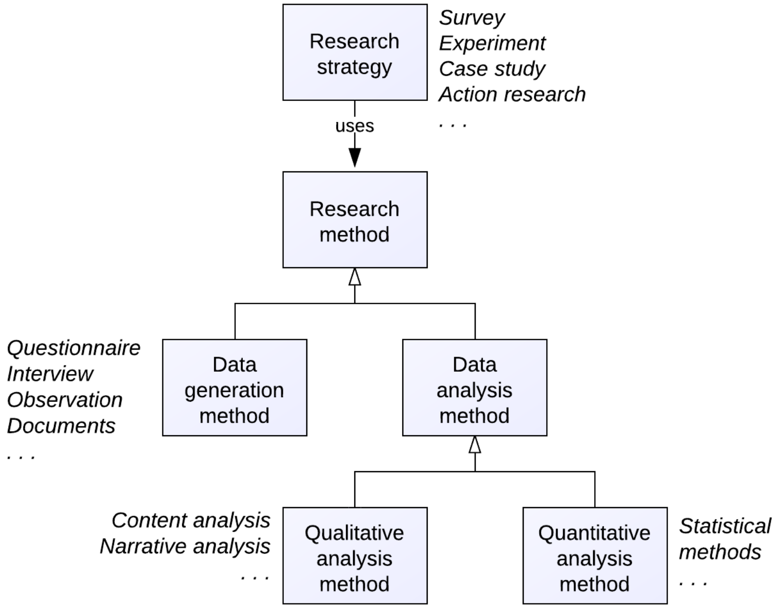

Figure 3.1 Research strategies and research methods

Figure 3.1 shows the relationships between research strategies, data generation methods, and data analysis methods. It also reads from top to bottom, as a simple guide to the initial decisions in a research project. First, the researcher will select one or more research strategies to be applied. For each research strategy, she will select one or more data generation methods to use as well as one or more data analysis methods. In practice, these decisions will not be as serial as suggested here but will rather develop in iterations during the entire research project.

A concrete example can be a researcher who intends to develop a method for designing business process models. The purpose here is to develop an artefact (a method). In order to gather requirements for the method, she chooses a survey as one of the research strategies in the project, where she tries to get suggestions for requirements from experts in business process management. For gathering information from the experts, she chooses to use interviews (a data generation method) and she analyses the gathered interview data using a qualitative method. In addition to the requirements elicitation, she also decides to evaluate the method. For this purpose, she chooses an experiment as the research strategy. She sets up a situation where students, as well as experienced process designers, are to use the method. She observes (a data generation method) the behaviour of these people when using the method and logs their results (another data generation method), which she later analyses using statistical (quantitative) methods.

Is a theory an artefact?

Short answer: No

Long answer: The answer may seem to be yes, as a theory is clearly created by humans. However, to count as an artefact in design science, an object should not only be man-made but also constructed with the intention to be used for addressing a practical problem. Thus, a theory is not an artefact, as it is not intended to address practical problems but to explain and predict phenomena and behaviours in some domain. A definition by Bhattacherjee (2012) states: “A theory is a set of systematically interrelated constructs and propositions that are advanced to explain and predict a certain phenomenon or behavior within certain boundary conditions and assumptions. Essentially, a theory is a systematic aggregation of theoretical propositions. While propositions connect two or three constructs at most, theories represent a system of multiple constructs and propositions."

Caveat: Even if a theory cannot be used to directly address a practical problem, it can help to design artefacts that do address such problems. In the words of Kurt Lewin, often recognized as the founder of social psychology: "There is nothing so practical as a good theory". In fact, design science requires that the design of artefacts always be based on a knowledge base, which preferably includes theories.

Further Reading

There are many books on research methodology both for natural and social science. This chapter closely follows the structure of research strategies and methods proposed by Denscombe (2010) and it is also close to the structure suggested by Bhattacherjee (2012).

4 A Design Science Method

Design science projects can be large undertakings, involving many people and being carried out over an extended period of time. Therefore, researchers can benefit from design science methods that support them in structuring their work and ensuring the quality of their results. Such methods can also support design researchers in presenting their work in a logical and easily understandable way. In this section, we introduce a generic design science method that can be adapted to the needs of specific research projects. The method proposed here is not another research strategy or method, such as those introduced in Chapter 3; rather it is a holistic approach to problem solving by means of artefacts, offering a framework of activities to be performed and questions to be answered.

4.1 Activities in Design Science

The design science method introduced here includes five main activities that range from problem investigation and requirements definition, through artefact development to demonstration and evaluation. These activities are outlined below and elaborated in detail in Chapters 5 to 9.

Explicate Problem

The Explicate Problem activity is about investigating and analysing a practical problem. It is to be precisely formulated and motivated by showing that it is significant for some practice. The problem should be of general interest, i.e., significant not only for one local practice. Furthermore, underlying causes to the problem may be identified and analysed.

Outline Artefact and Define Requirements

The Outline Artefact and Define Requirements activity is to outline a solution to the explicated problem in the form of an artefact. Requirements are to be determined, which can be seen as a transformation of the problem into demands on the proposed artefact. The requirements will be defined primarily for functionality but also for construction and environment.

Design and Develop Artefact

The Design and Develop Artefact activity aims to create an artefact that addresses the explicated problem and fulfils the defined requirements. Designing an artefact includes determining its functionality as well as its construction.

Demonstrate Artefact

The Demonstrate Artefact activity uses the developed artefact in an illustrative or real-life case, sometimes called a "proof of concept", thereby proving the feasibility of the artefact. The demonstration shall show that the artefact actually can solve an instance of the problem addressed.

Evaluate Artefact

The Evaluate Artefact activity is to determine how well the artefact fulfils the requirements and to what extent it can solve, or alleviate, the practical problem that motivated the research.

An overview of the proposed design science method is shown in figure 4.1, which also indicates the results from each activity. The method, as described here, may look highly sequential. However, a design science project is always carried out in an iterative way, moving back and forth between all the activities of problem explication, requirements definition, development and evaluation. This way of working is fully in line with the proposed design science method, as it does not prescribe a sequential work ordering. The arrows in figure 4.1 should not be interpreted as temporal orderings but as input-output relationships. In other words, the activities are not to be seen as temporal groupings of work to be performed in sequence but instead as logical groupings of work. These issues are further elaborated in Chapter 11.

Is design science the same as action research?

Short answer: No

Long answer: The purpose and activities of design science are close to those of action research. Both aim to change and improve human practices and thus can be viewed as practice research, as pointed out by Goldkuhl (2012). Furthermore, both include problem solving and evaluation. However, there are also differences. Design science addresses practical problems through the design and positioning of artefacts, while action research does not require an artefact to be part of the solution addressing the practical problems. Instead, action research addresses problems through psychological, social and organizational change. Furthermore, design science does not require a practical problem from a specific organisation as the starting point for the research, while this is required in action research. Finally, action research is a single research strategy, while design science can make use of many different research strategies, e.g. one for problem explication, another for requirements definition and a third for evaluation.

Caveat: It could be argued, however, that if an artefact is proposed as a solution in an action research project, action research becomes very similar to design science. Clearly, action research is a highly relevant research strategy for many design science projects, and there are also design science methods based on action research, e.g. (Sein et al. 2011).

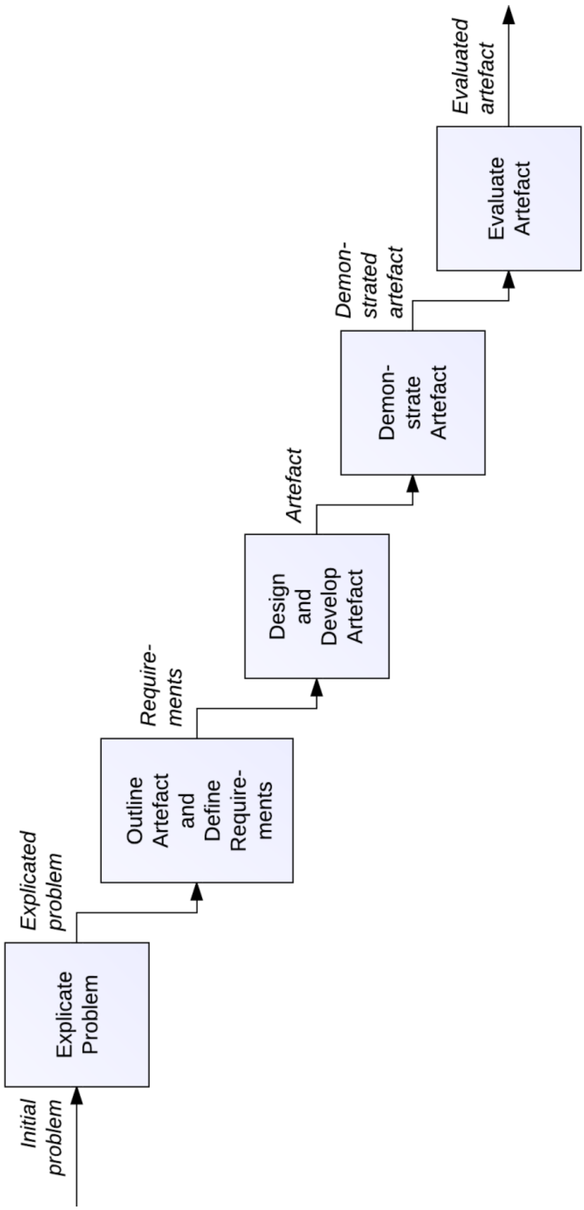

Figure 4.1 Overview of the Design Science Method

4.2 Research Strategies and Methods in Design Science

The purpose of design science is not only to create artefacts but also to answer questions about them and their environments. In order to ensure that the answers express valid and reliable knowledge, the use of research strategies and methods are vital. Within design science, it is possible to use any research strategy or method to answer questions about artefacts. In other words, no research strategies or methods can be excluded in advance for a design science project, as any of them may be valuable depending on the project's characteristics and goals.

In large design science projects, it is even common to use several research strategies and methods, because different design science activities may require different approaches. For example, a survey can be an appropriate instrument for eliciting requirements, while an experiment can be the best choice for evaluation. Figure 4.2 outlines commonly used research strategies for design science activities; it should be seen as merely indicative, as any research strategy can be used in any activity.

For problem explication, surveys are effective instruments, as they can be used to quickly gather opinions and perceptions about a problem situation from a large number of stakeholders. However, the results from surveys are often superficial, as stakeholders may not be prepared to spend much time and effort on describing and analysing the problem under consideration. A deeper understanding about a problem and its context can be achieved through a case study, where researchers investigate the problem for an extended period of time, using interviews, observation and document studies. However, results from case studies may be difficult to generalise if they are based only on one local practice.

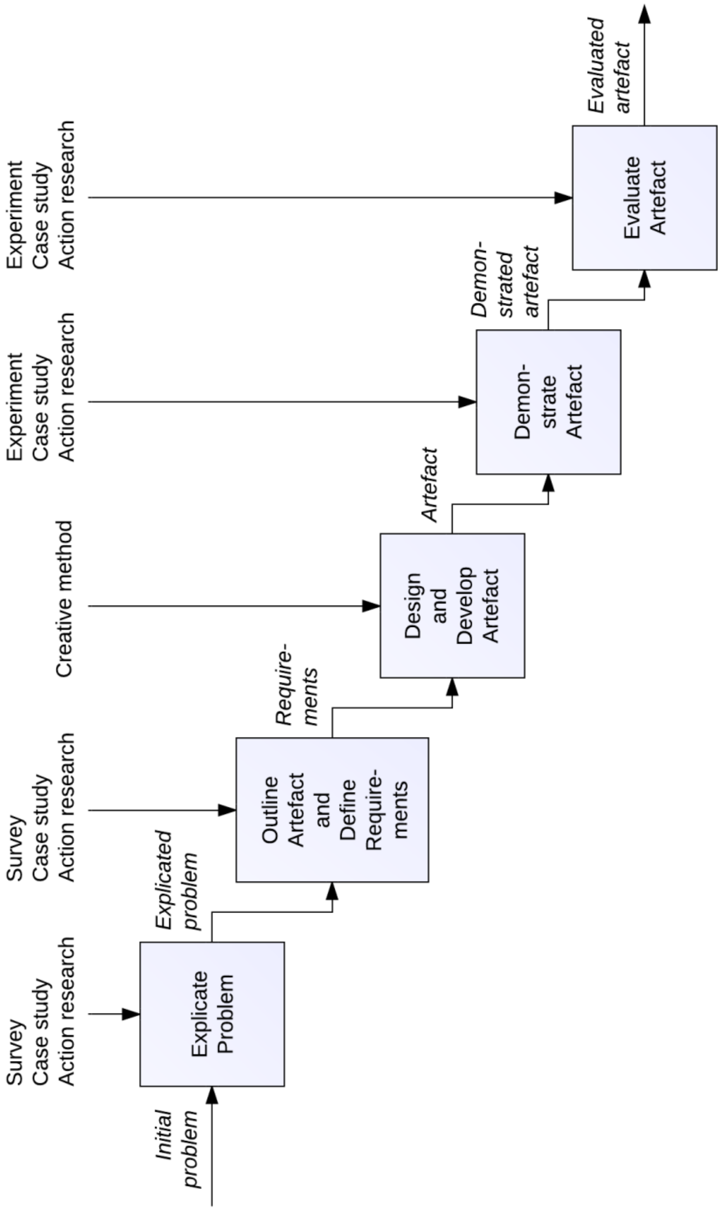

Figure 4.2 Suggested use of research strategies in the design science method

For requirements definition, surveys are also effective instruments. However, it may be hard for stakeholders to suggest relevant requirements when the artefact to be designed is highly innovative or complex. In such cases, action research and case studies may be better alternatives, as they allow a researcher to identify requirements herself, without having to rely on stakeholders to be inventive and committed. A drawback is that requirements definition may become heavily dependent on the competence and experience of the researcher.

For design and development, research strategies are often less important, as the primary goal of this activity is to produce an artefact and to a lesser extent, the knowledge about it. Instead, creative methods are more relevant, e.g., brainstorming, participative modelling, empathetic thinking and lateral thinking.

Demonstration is about using an artefact in a specific case to show its feasibility. Thus, the most obvious research strategies to apply are action research and case studies, which will typically include interviews and observations of people in their use of the artefact.

For evaluating an artefact, experiments are popular instruments, as they allow a researcher to achieve high internal validity by carefully controlling the conditions under which an experiment is undertaken. On the other hand, external validity can suffer, because the artificial setting of the experiment can be decidedly different from the practice in which the artefact is to be used. An alternative is to use case studies or action research, where the artefact is used and evaluated in a local practice.

4.3 Relating to a Knowledge Base

The results from a design science project should be original and well founded. Therefore, it is required to relate both design science activities and their results to an existing knowledge base. Such a knowledge base may include models and theories from several fields of science. In the IT and information systems area, theories from social and behavioural sciences are particularly relevant but also models from formal sciences. Furthermore, a knowledge base will typically include information about artefacts similar to the one under consideration.

Relevant knowledge may be found in academic publications, including textbooks and research papers in journals and conferences. A good starting point for identifying these kinds of publications is Google Scholar. Other sources of knowledge include magazine articles, white papers, fair trade presentations and artefact manuals.

4.4 Typical Cases of Design Science Projects

Many design science projects do not undertake in depth all of the five activities of the design science method. Instead, they may focus on one or two of the activities, while the others are treated more lightly. Based on their focus, it is possible to distinguish between at least five typical cases of design science projects.

Problem focused design science

Some design science projects focus on problem explication. They carefully investigate a problem situation and divide it into subproblems, and may also carry out a root cause analysis. They thereby employ research strategies and methods in a rigorous way and typically include comprehensive empirical studies. These projects also define requirements on an artefact based on more or less careful investigations. The design of the artefact is only outlined and neither demonstration nor evaluation is carried out. Projects of this kind often have a strong social science flavour and the design element is downplayed. However, they can provide essential problem understanding upon which subsequent design science projects can build.

Requirements focused design science

Other design science projects focus on requirements definition. These projects start with an existing problem that is simply accepted as is, or slightly explicated. Careful and rigorous investigations are carried out in order to collect requirements, which will involve literature studies, as well as interaction with relevant stakeholders. The design of the artefact is only outlined and neither demonstration nor evaluation is carried out.

Requirements and development focused design science

Many design science projects focus on a combination of requirements definition and artefact development. Such projects will not perform any problem explication but move directly to requirements definition, which is carried out in a rigorous way. The artefact is then developed using research as well as creative methods. The viability of the artefact is demonstrated or a lightweight evaluation is performed.

Development and evaluation focused design science

It is also common that design science projects focus on development and evaluation. Such projects will neither perform problem explication nor requirements definition but start from an existing requirements specification. The focus will be the design and development of an artefact using both research and creative methods. There will also be a demonstration and a thorough evaluation by means of experiments, case studies, or other research strategies.

Evaluation focused design science

Some design science projects focus on the evaluation activity. Thus, no artefact is developed, nor even outlined and therefore, it could be questioned whether such a project should count as design science, see the box below for a discussion. Evaluation projects often include careful requirements definition, which results in a requirements specification used as a basis for the evaluation. The evaluation is carried out in a rigorous way using adequate research strategies and methods.

Can an evaluation study be design science?

Short answer: Yes

Long answer: Consider a study that does not design and develop a new artefact but only evaluates an existing one. Can such a study count as design science? At first glance the answer seems to be no, as design science is about the development of novel artefacts. However, an evaluation study can be part of a larger design science undertaking, which may extend over a long time involving a number of research groups and individuals. One study may explicate a problem and suggest an artefact that can help to solve it; another study may define requirements on the artefact; a third study may develop the artefact; and yet another study may evaluate it. All of the studies are part of the same design science undertaking, although the same people do not necessarily carry them out. In this sense, the studies can all be viewed as design science contributions.

The question about evaluation studies can be generalised to problem explication studies, requirements definition studies and artefact designs. Using the same argument as above, all such studies can count as design science. Even if none of them covers all the design science activities, together they extend the knowledge about an artefact and its context.

Caveat: Even if very narrow studies can still count as design science, they may not meet the requirements for a bachelor, master or PhD thesis within certain study programs.

4.5 Visualizing the Design Science Method

The proposed design science method can be visualized using IDEF0, which is a technique for describing systems as a number of interrelated activities, graphically represented as boxes, see figure 4.3. Each activity can be decomposed into sub-activities, which themselves can be decomposed into further sub-activities, and so on. Furthermore, channels conveying data or objects are related to each activity.

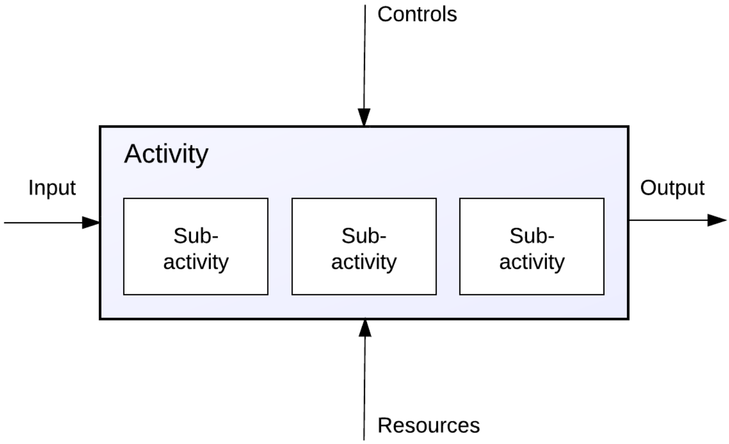

Figure 4.3 IDEF0 diagram

Four kinds of channels are used in IDEF0: input, output, control and resources. Inputs are transformed or consumed by an activity to produce outputs. Controls (e.g., blueprints, rules, guidelines, methods and instruments) govern an activity to produce correct outputs, while resources are the means (e.g., generic and domain knowledge) that support an activity. Channels are represented graphically as arrows; input arrows point to the left side of a box; output arrows leave the right side of a box; control arrows point to the top side of a box; and resource arrows point to the bottom of a box.

In the design science method, the channels can be defined as follows:

– *Input* (arrow from left) – describes what knowledge or object is the input to an activity
– *Output* (arrow to right) – describes what knowledge or object is the output from an activity
– *Controls* (arrow from above) – describe what knowledge is used for governing an activity, including research strategies, research methods, and creative methods
– *Resources* (arrow from below) – describe what knowledge is used as the basis of an activity, i.e. the knowledge base including models and theories

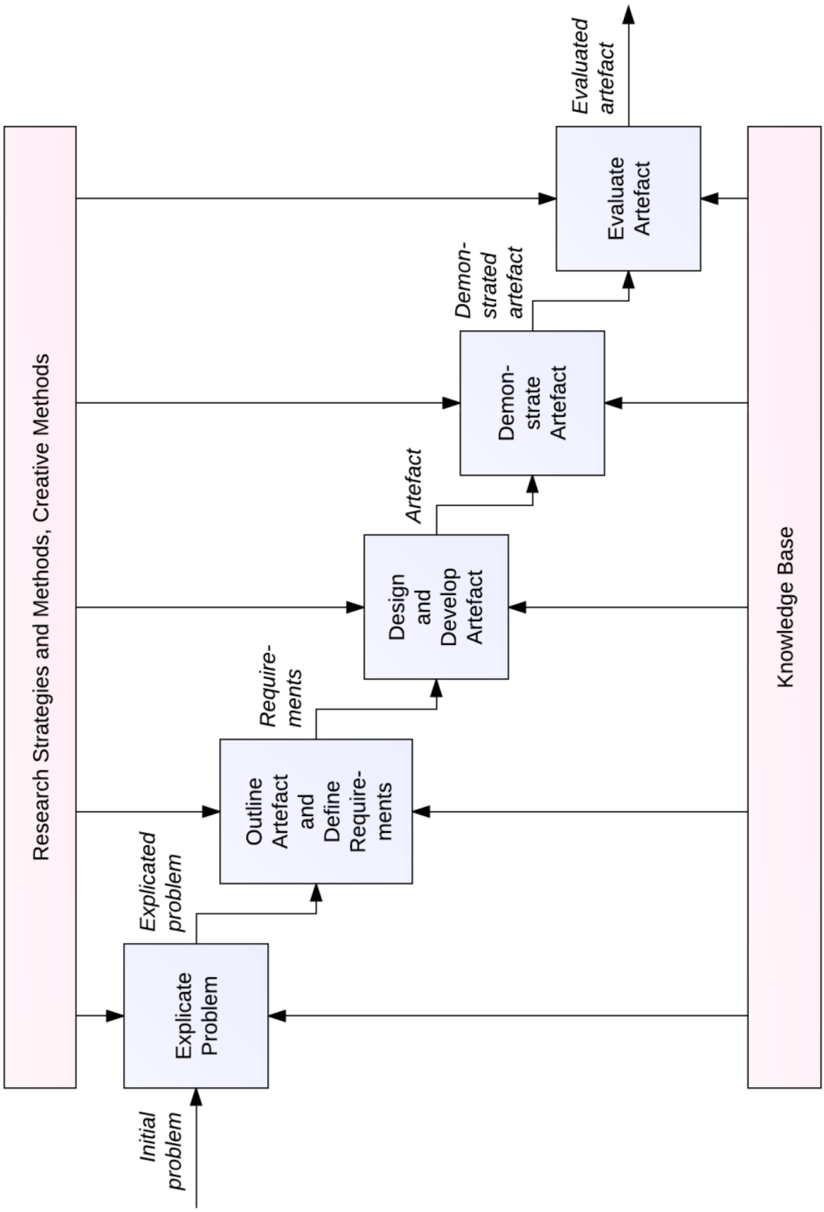

Figure 4.4 IDEF0 diagram for the Design Science Method

Figure 4.4 displays the design science method as an IDEF0 diagram. When applying the method in a design science project, the diagram may be used as a template and filled in with the specifics of the project. This will result in a convenient overview of the project, which can be used for documentation and communication.

Must a design science project always create a new artefact?

Short answer: No

Long answer: The purpose of a design science project is to address a practical problem by means of an artefact. The project may develop a new artefact from scratch or refine an existing one. The project can even repurpose an existing artefact, i.e. use it for a new purpose without changing it. An existing artefact is used to solve another problem than that for which it was originally designed and developed. For example, the anticoagulant chemical Warfarin was introduced as a rat poison but later repurposed as a blood thinning medicine. Gunpowder started out as a medical elixir in China centuries before it was repurposed for powering fireworks and firearms. Thus, a design science project does not have to create a new artefact as it may transform an existing one into something entirely different through repurposing. In terms of the design science method suggested in this book, such a project would skip the activity Design and Develop, while the other activities would still be addressed.

4.6 The Design Science Canvas

Through the IDEF0 representation of the design science method, it is possible to obtain a comprehensive, yet compact overview of a design science project. However, it is sometimes desirable to get an even more compact description and for this purpose, the *Design Science Canvas* can be used. The Canvas offers a concise, easily understandable and visually appealing overview of the key components of a design science project. The Canvas consists of a rectangle divided into a number of fields that describe the artefact under consideration, the problem it addresses, the knowledge base used, the requirements on the artefact, the research strategies and methods used in the project, and the results of the project.

Problem
Describe a practical problem to be addressed. Formulate it in a precise and concise way. Motivate the problem by explaining why it is of general interest, significant, challenging and possibly original. Specify the stakeholders of the problem.

Artefact
State the type of artefact: Construct, Model, Method, or Instantiation. Describe the artefact and how it is to be used in its intended practice. Explain why and how it can address the problem.

Knowledge Base
Describe the knowledge base that is used as a foundation for the work. The knowledge base may include theories and models as well as existing artefacts. Explain how the knowledge base has been utilized.

Practice
Describe the practice in which the practical problem exists, in particular its purpose, main activities and participants.

Requirements
Describe requirements on the artefact. Include requirements pertaining to function as well as construction and environment. Justify the requirements by relating them to stakeholder interests.

Constructs
Define, describe and explain the most important constructs that are used in the work.

Explicate Problem
What is the problem experienced by some stakeholders of a practice and why is it important? Describe and justify the methods used.

Define Requirements
What artefact can be a solution for the problem and which requirements are important for the stakeholders? Describe the methods used.

Develop Artefact
Create an artefact that addresses the explicated problem and fulfils the defined requirements. Describe and justify the methods used.

Demonstrate Artefact
How can the artefact be used to address the explicated problem in one case? Describe and justify the methods used in this task.

Evaluate Artefact
How well does the artefact solve the explicated problem and fulfil the defined requirements? Describe and justify the methods used.

Construction
Describe the internal structure of the artefact, i.e. its components and their relationships and interactions. Discuss design rationale.

Function
Describe the functions offered by the artefact. Explain how the construction of the artefact gives rise to the functions. Discuss how the functions contribute to fulfilling the requirements.

Usability
Discuss the usability of the artefact and how it can be improved, in particular processes and guidelines that can make it easier to use the artefact.

Effects
Discuss the effects of the arte-fact, direct and indirect as well as intended and unintended. Identify practices and resources that can be affected by the artefact and discuss them with respect to ethical and societal aspects.

Figure 4.5 The Design Science Canvas

A template for the Design Science Canvas with descriptions of the fields is presented in figure 4.5. A more detailed version of the Canvas can be found at goo.gl/TKD5S. The top part of the Canvas (blue in the figure) defines the artefact under consideration, the problem being addressed and the knowledge base used in the work. The middle part (yellow in the figure) describes the activities of the design science method, corresponding to Chapters 5 to 9. The bottom part (red in the figure) shows the results of a design science project in terms of the construction, function, usability and effects of the artefact.

The Design Science Canvas may be used in several different situations. It can be used as a first sketch in order to improve communication and common understanding between members of a new design science project. It can also be used as a monitoring tool for continuously recording changes to the plans for a project. Furthermore, the Canvas can help to present the overall setup of a project to stakeholders and other interested parties. A similar use is to include the Canvas in the final project report as part of an executive summary. In general, the Canvas is useful whenever there is a need to get a compact and easily understandable overview of a design science project.

Can the Design Science Canvas help to structure thesis work?

Short answer: Yes

Long answer: The Design Science Canvas can serve as a communication tool for the participants in a thesis work, including authors, employers, supervisors, examiners, fellow students, and other interested parties. In the initial stage, a draft of the Canvas can function as a plan for the thesis project, particularly by outlining those parts of the design science method that are in focus. Later on, the Canvas can be regularly updated to reflect the progress of the work, thereby becoming more and more detailed. The Canvas can also help to structure the thesis text, as the Canvas fields can work as summaries of key parts of the thesis. Thus, the

Canvas can be used to structure the thesis project, as well as the thesis text and it can support communication among the stakeholders of the project.

4.7 Running Example

In order to illustrate the use of the design science method, a fictitious running example is presented in Chapters 5 to 9. In recent years, a number of publishing houses have experienced decreasing sales of books, as reading books in general is in decline, at least when compared to other kinds of media consumption. In particular, young people seem to be less and less interested in book reading. At the same time, the Internet and mobile technologies offer many opportunities for enriching the book reading experience but these have not been fully exploited as yet. Publishing houses believe that they need to make a joint effort to address the problem and grasp the new opportunities. They also realise that the problem is complex and in need of research if it is to be adequately addressed. The publishing houses, together with a number of university researchers, have therefore decided to launch a design science project to address this problem by designing a novel artefact that will increase interest in book reading. The project is called DIGIREAD and is further described in Chapters 5 to 9.

What are the similarities and differences between the scientific method and the design science method?

According to the Oxford English Dictionary, the scientific method is "a method or procedure that has characterized natural science since the 17th century, consisting in systematic observation, measurement, and experiment, and the formulation, testing, and modification of hypotheses". One common version of the scientific method is the hypothetico-deductive method, which is typically divided into four steps:

1 *Ask a question.* The researcher observes some phenomenon that is novel, surprising, or interesting for some other reason. She attempts to

capture the relevant aspects of the phenomenon by asking a question about it.

2 *Form a hypothesis.* The researcher comes up with and formulates a hypothesis that is able to answer the question. This hypothesis often includes a causal mechanism or a predictive model. The hypothesis may also be made up of a set of smaller, interrelated hypotheses.

3 *Deduce predictions from the hypothesis.* Assuming the hypothesis is true, the researcher identifies some consequences that must then hold, i.e. she makes a number of predictions.

4 *Check the predictions.* The researcher performs observations to determine whether the predictions are correct or not; if correct, the hypothesis is strengthened, otherwise it is weakened.

The design science method is aligned with the scientific method. Its first activity, *Explicate Problem*, is similar to *Ask a question* of the scientific method, as both investigate a situation that is experienced as challenging. The difference is that in the scientific method, a question is asked, while a practical problem is examined in design science. Step 2, *Form a hypothesis*, is similar to activities 2 and 3 of the design science method, which first identify requirements on an artefact and then design and develop it. However, in the scientific method an answer is formulated in the form of a hypothesis, while design science produces an artefact. Steps 3 and 4 of the scientific method correspond to *Evaluate Artefact* of the design science method, as both intend to show that the results produced are satisfactory. Summarizing, steps 1 and 2 of the scientific method, as well as activities 1 to 3 of the design science method, are about discovery and invention, i.e. creating a new hypothesis or artefact. Steps 3 and 4 of the scientific method, as well as activities 4 and 5 of the design science method, are about justification, i.e. ensuring that the created hypothesis or artefact is adequate.

Further Reading

The design science method of this chapter is close to the one proposed by Peffers et al. (2007), though we have omitted the communication activity and emphasized requirements elicitation. Other similar methods have been proposed by March and Smith (1995) and Vaishnavi and Kuechler (2004).

5 Explicate Problem

The first activity of the design science method is Explicate Problem. The goal of this activity is to formulate precisely the initial problem, motivate its importance, and investigate its underlying causes. In other words, it addresses the question:

> What is the problem experienced by some stakeholders of a practice and why is it important?

The answer to this question primarily consists of descriptive knowledge about the characteristics and environment of the problem. Sometimes, the answer will also include explanatory knowledge about problem causes.

As discussed in Chapter 1, a problem is an undesirable state of affairs, or more precisely, a gap between the current state and a desirable state. For example, suppose that several customers complain about the long delivery times of a company. The customers expect the time from order placement to product delivery to be less than one week (desirable state) instead of the current three weeks (current state). Thus, this is the gap, which constitutes the problem.

The gap between the desirable and the current state is not always made explicit when a problem is discussed. Often, the gap is so obvious that knowledge of the current state is sufficient to conclude that a problem exists. For example, if many customers of a company complain about delivery times, its management will realise that customers are dissatisfied and that there exists a problem to be addressed. In this case, the desirable state is not explicitly stated. In other cases, a problem may become apparent only when someone suggests a more desirable state of affairs. For example, suppose that no customer has complained about the delivery times, but a competitor states in a marketing campaign that its delivery time is only three days from order placement. If the management interprets this as a threat, there will be a problem, although the current state was not viewed as undesirable in itself.

Not only threats but also opportunities can be viewed as problems. An example is an organization that receives information from its ERP vendor that mobile phones can be integrated with its ERP system. Thereby, the employees can access the system from anywhere, which will increase their productivity. Therefore, the problem is that the organisation currently does not work as productively as possible, because its employees do not benefit from this opportunity of mobile technology.

The activity Explicate Problem can be structured and visualized using the IDEF0 technique, see figure 5.1. The input is an initial problem that can be vaguely formulated. The output is an explicated problem, which is precisely defined, well-motivated and put into a context. The resources used by the activity consist of knowledge in the research literature and other written sources, as well as information from relevant stakeholders. The controls are primarily research strategies and methods but may also include other practice-based approaches to problem elicitation and representation.

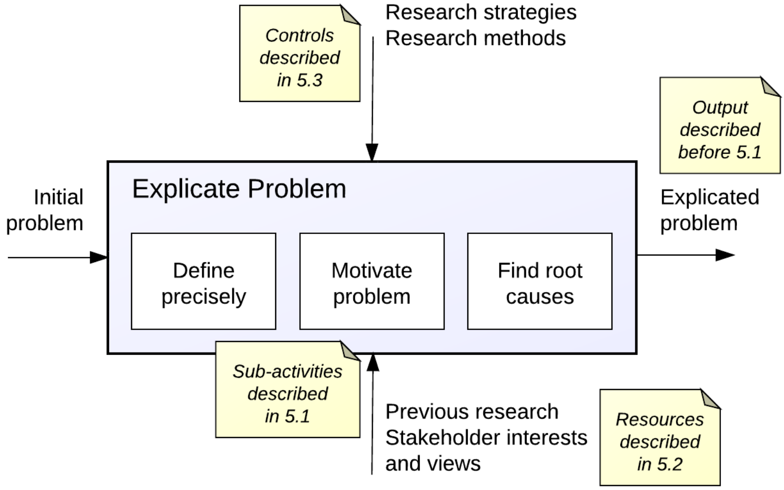

Figure 5.1 Explicate Problem

5.1 Sub-activities of Explicate Problem

When the initial practical problem is obscurely expressed or incompletely understood, there is a need to investigate it, so that researchers can suggest an appropriate solution. However, in some cases, the initial problem is already understood and clearly articulated, meaning that the Explicate Problem activity will be small. Problem explication consists of three main sub-activities: making the problem definition as precise as possible, motivating the problem and finding root causes.

Define precisely

A problem should be defined as precisely as possible so that different people understand it in the same way. A problem definition is made more precise by reducing the number of ways in which it can be understood and interpreted. For example, a problem definition such as "non-integrated IT systems result in long delivery times for organisations" is vague and may be interpreted in many different ways. It can be made more precise by being reformulated as "the lack of integration of IT systems supporting the order management process and the delivery process, results in long delivery times for organisations". The second definition has fewer possible interpretations than the first one. In general, precise problem definitions are to be preferred over less precise ones, as they support people better to develop a common view of a problem. However, highly precise problem definitions can sometimes be difficult to quickly grasp and understand.

Motivate Problem

A problem should always be well motivated so that people can agree it is worthwhile to address. The problem should be significant for some practice, i.e., viewed as important by stakeholders who want to find a solution to it. Furthermore, the problem should be of general interest, i.e., it should not matter only to a single local practice. The problem should also be challenging, in the sense that a solution to it does not already exist. Sometimes a problem can be original, which is particularly common when technological innovations have created new opportunities. The motivation of a problem may also include its ethical and societal consequences.

Find Root Causes

In an early stage, a problem often expresses some symptom of underlying causes that are as yet unknown. In order to address the problem effectively, a so-called root cause analysis can be performed, where the underlying causes are identified, analysed and represented. By addressing these causes, better results can be achieved than by only treating the symptoms of the problem. For example, an initial problem may be expressed as "the company has delivery times that are too long". A root cause analysis may indicate that the main reason for this problem is the lack of integration between the IT systems managing the order management process and the delivery process. Consequently, time-consuming manual administrative work has to compensate for the lack of systems integration. Thus, the underlying problem can be defined as "non-integrated IT systems result in long delivery times for the organisation". The focus may then shift from the initial problem to this underlying problem.

One widespread tool for representing problem causes is the Ishikawa diagram (also called cause-effect diagram or fishbone diagram), see figure 5.2 for an example. An Ishikawa diagram is a graphical tool used to investigate and represent potential causes of a problem. It consists of a main horizontal line representing the problem and associated slanting lines representing direct problem causes, which in their turn may be related to additional lines representing indirect problem causes. The causes can also be classified into different categories, as indicated in figure 5.2.

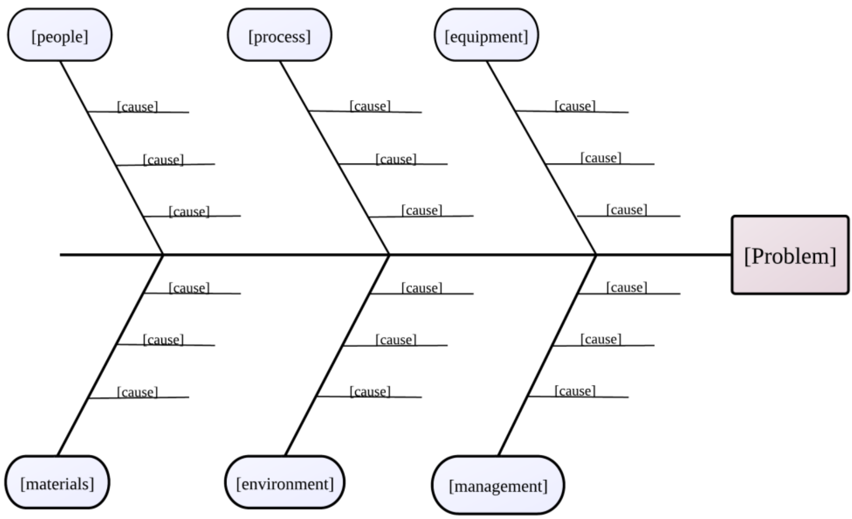

Figure 5.2 Ishikawa diagram

5.2 Resources for Explicate Problem

The results of the activity should be based on and compared with existing related work. Therefore, the researcher needs to investigate what previous research has addressed similar problems and existing solutions. Not just research literature can be used but also other sources, e.g., newspaper articles and white papers.

In some cases, a researcher can base a problem explication solely on literature, but usually she also needs to directly study participants and stakeholders of relevant practices. Stakeholders in the practices may themselves express views and opinions about a problem, which then are to be interpreted by the researcher. She can also gain a better understanding of the practices by observing participants in their daily activity. Furthermore, the researcher will often need to study different groups of stakeholders, e.g. managers, employees and customers, as they may have different views and knowledge about various aspects of the problem. By combining contributions from different stakeholder groups, the researcher can achieve a deeper and more complete explication of the problem.

5.3 Strategies and Methods for Explicate Problem

Research Strategies for Explicate Problem

Surveys

Surveys can be used for eliciting problem statements from a large group of stakeholders. Thereby, they provide an overview of problems experienced by, for example, managers, employees, end-users and customers. In many cases, different stakeholders have different views of the problem at hand, and a survey can make these differences explicit. However, a survey is typically not an effective instrument for eliciting a deep and elaborated problem analysis from stakeholders.

Case studies

Case studies can provide a deep understanding of the practice in which the initial problem emerged. This establishes a firm grasp of the root causes to the problem as well as the stakeholders' views on the problem. However, case studies are complex undertakings that heavily rely on the skills and experiences of the researcher performing them. This dependency on the individual researcher may be a drawback, as she may have interests and preconceptions that can bias the research work.

Action research

Action research requires an active engagement of researchers in a practice. The competence and experiences of the researchers may offer fresh perspectives on the problem that are not obvious to the stakeholders of the practice. Furthermore, new and more important problems can emerge when the researchers are discussing opportunities and presenting solutions to the stakeholders. However, the dependency on the researchers is strong due to their active participation in the practice. Therefore, there is a risk that their interests and preconceptions will have too much influence on the problem explication.

Grounded Theory

Grounded theory is a research strategy in which pure empirical facts have a strong impact on the explication of a problem. The researchers start by gathering facts about the domain under consideration. Based on these facts, they suggest a first problem explication, which is tested against further empirical facts from the domain, resulting in a refined problem explication. The iterations between fact gathering and problem explication refinement continue until further empirical facts have no effect on the problem explication. An advantage of grounded theory is the lack of any restriction by any specific theoretical view that may limit the researchers. However, this is also a disadvantage, as a theoretical lens can support the researchers in finding new perspectives on the problem.

Ethnography

The research strategy ethnography allows a researcher to understand the culture of a practice in depth. Thereby, she is able to see the problem not only as an outsider but also from the stakeholders' point of view. Furthermore, based on her competence and experience, the researcher may understand the structures behind the stakeholders' views and actions, which they themselves might not recognise. This knowledge can allow the researcher to arrive at a deep and rich problem explication. However, because ethnographical studies are time-consuming, she may only be able to understand a limited number of stakeholders, while other stakeholders may not be considered. The outcome of this research strategy also heavily relies on the competence and experience of the researcher.

Research Methods for Explicate Problems

Interviews

Interviews allow a researcher to engage in a dialogue with a respondent in order to explicate a problem in an interactive and creative way. This is possible because the researcher, based on the respondent's initial answers, can ask follow up questions. A drawback of interviews is the dependency on the perspective and interests of the respondent, but this problem can be mitigated by interviewing several respondents.

Group discussions

A group discussion is a research method where several respondents in conversations may inspire each other to identify and define problems in a domain. However, there is a risk that dominant individuals in such a discussion have too great an impact so that other opinions are not voiced. Therefore, it may be necessary for a skilled moderator to manage a group discussion.

Questionnaires

A questionnaire is a form that contains predefined written questions. A main benefit of using questionnaires for data generation is that they can easily, and with low cost, be distributed to a large number of respondents. A drawback is that a researcher and a respondent cannot discuss a problem situation informally and creatively. Another drawback is that respondents can interpret the written questions of a questionnaire in different ways.

Observation studies

In an observation study, researchers can observe the behaviour of people in a practice. A benefit of the method is that researchers, based on their competence and experience, can identify problems and circumstances that are not apparent to the people under observation. A drawback is that the method requires highly skilled researchers to interpret the actions and interactions of the people investigated. There is also a risk that the interests and preconceptions of the researchers may influence their interpretations in unwanted ways.

Document studies

A document study is a form of an observation study but the focus is on written documents, not actions. Written documents can expose contradictions in a practice and, therefore, be a valuable source for identifying and defining problems. However, the method requires skilled researchers for interpreting the documents. There is also a risk that some documents only show the official view of some actor and may hide existing problems.

5.4 Guidelines for Explicate Problem

The results of the problem explication will govern the rest of the research process. Therefore, a thorough problem explication will be valuable for all the other design science activities. The following guidelines can be used to support problem explication.

- *Position the problem!* Clarify in which practice the problem appears.
- *Formulate the problem precisely!* Describe the problem in a precise but also concise, easily understandable manner.
- *Motivate the problem!* Explain why the problem is important and for whom.
- *Ensure the problem is of general interest!* Make clear that the problem is of interest not only to a local practice.

- *Ensure the problem is solvable!* Define and analyze the problem so that it becomes small enough to be solved.
- *Specify the sources of the problem!* Describe the literature and the stakeholders that have previously identified, studied and experienced the problem.
- *Describe how you have explicated the problem!* Explain what you have done to explicate the problem, in particular how you have reviewed the stakeholders and research literature.

5.5 Running Example

The first activity for DIGIREAD, presented in Section 4.7 as a running example, was to explicate the problem. There were three sub-activities: defining the problem precisely, motivating the problem and finding the root causes.

The first sub-activity was to define the problem precisely in order to reduce the number of ways in which it might be understood and interpreted. The initial problem was formulated: book reading is in decline. In order to formulate this still more precisely, a thorough empirical survey could then have been carried out. However, in this case, the sub-activity was based on public statistics showing that people between the ages of 15 - 25 in particular spend less time reading books today compared to people of the same age either 5 or 10 years ago. A more precise problem was therefore formulated as: book reading is in decline among people between the ages of 15 - 25.

The second sub-activity was to motivate the problem so that the stakeholders can agree it is worthwhile to address it. For the publishing houses, this is clearly a major problem as it threatens future sales.

The third sub-activity was to find the root causes of the problem so that better results could be achieved than by simply treating the symptoms of the problem. In this case a thorough investigation was carried out by the researchers, and a survey was chosen as the research strategy. The survey targeted young people who had given up book reading in favour of social media interaction, web browsing, watching television or other kinds of media consumption. Five hundred randomly selected persons between the age of 15 - 25 were asked about their media preferences. The ten per cent least committed to book reading was then selected for a second questionnaire. This questionnaire consisted mainly of open questions, where the respondents were encouraged to explain why they had abandoned reading books. The answers were analysed using content analysis, and a number of root causes were identified. Finally, media theory, in particular critical media theory, was used to identify further causes for the current decline in reading. The most important causes identified were the following:

- Paper books are awkward to handle
- It is wearisome to read long texts
- Books are not interactive
- Books and book contents cannot easily be shared
- Book contents are not easily combined
- Many people see publishing houses as promoting their own interests

The Explicate Problem activity is summarized in figure 5.3.

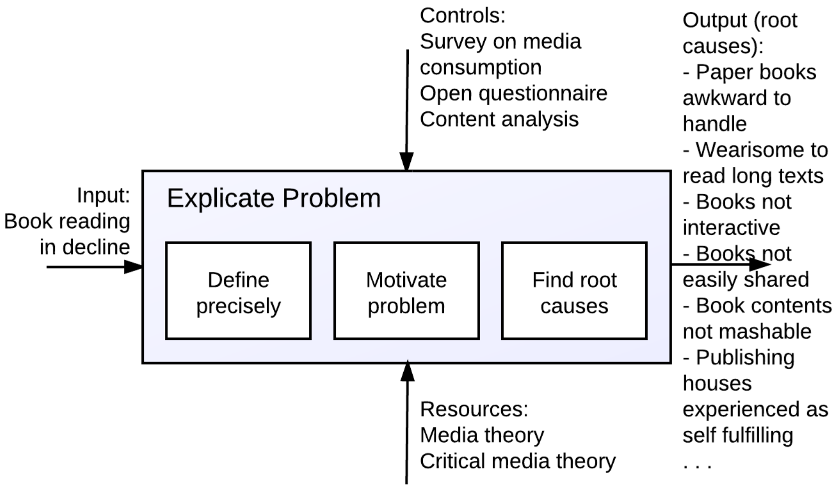

Figure 5.3 Explicate Problem in the running example

Further Reading

A classic text on problem analysis and solving was written by Polya (1973), although it is quite mathematically oriented. Ritchey (2007) gives an easily accessible introduction to wicked problems. Ishikawa diagrams are described on the web page Cause and Effect Analysis (2012).

6 Outline Artefact and Define Requirements

The second activity of the method is Outline Artefact and Define Requirements. The goal is to identify and outline an artefact that can address the explicated problem and to define requirements. In other words, the activity addresses the question:

> What artefact can be a solution for the explicated problem and which requirements on this artefact are important for the stakeholders?

Answering this question can be viewed as an extended problem explication. In other words, in this activity, researchers will continue to explicate further the problem, but they will do so using the proposed solution outline as a pair of glasses for guiding their problem examination. Thus, the question is to be answered by descriptive knowledge that specifies which requirements on the artefact are important for the stakeholders.

The requirements will primarily address the function and construction of the artefact but also the relationships to its environment. *Functional requirements* depend on the problem to be addressed, as well as the needs and wants of the stakeholders. Some examples of functional requirements for an electronic health record system could be to provide storage of X-rays, to enable doctors to enter information that will be unavailable to patients, or to allow patients to enter information on their self-medication. As can be seen from this example, functional requirements are often very specific to the situation at hand. In contrast, requirements pertaining to construction and environment are often more generic. Examples on *construction requirements* for the health record system could be that it should have a coherent and modular design. Examples on *environment requirements* could be that the system should be available on different platforms and be easy to adapt to changes. *Non-functional requirements* is a term encompassing both construction requirements and environment requirements.

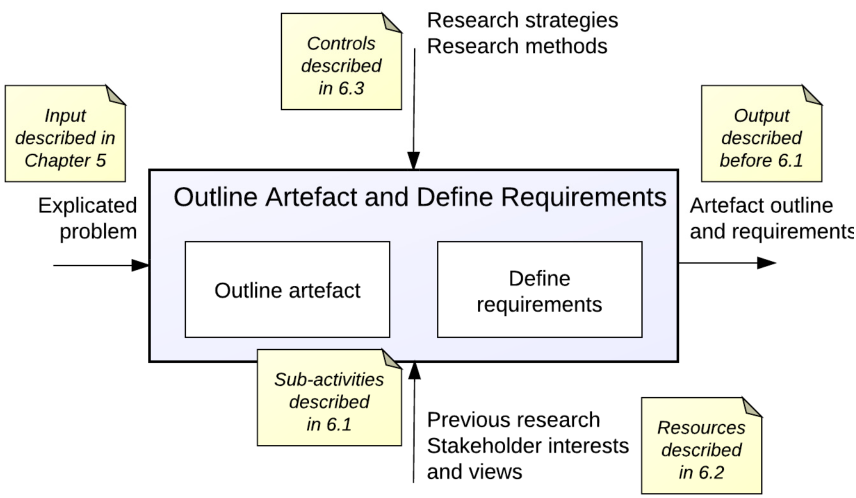

Figure 6.1 Outline Artefact and Define Requirements

The activity Outline Artefact and Define Requirements can be structured and visualized using the IDEF0 technique, see figure 6.1. The input is an explicated problem provided by the previous activity. The output is an artefact outline and a set of requirements. The resources used by the activity consist of knowledge in the research literature and other written sources, as well as assertions from stakeholders. The controls are primarily research strategies and methods but may also include practice-based approaches to requirements elicitation and analysis.

6.1 Sub-activities of Outline Artefact and Define Requirements

The activity includes two main sub-activities: outline artefact and define requirements.

Outline Artefact

The sub-activity outline artefact starts by choosing which artefact type should be designed in order to solve the problem, i.e. choosing whether the solution should be a construct, a model, a method or an instantiation. This choice is sometimes simple due to the characteristics of the explicated problem. In other cases, it can be more difficult to choose the artefact type to be designed. For example, if IT systems need to be integrated to make a process more efficient, a solution can be a *method* for integrating IT systems, a *model* of an integration architecture, or an *instantiation* in the form of an integration tool. When the artefact type has been chosen, the artefact is to be described on an overview level.

Define Requirements

The second sub-activity is to define the requirements on the outlined artefact. The requirements to include depend on the characteristics of the problem, the outlined solution, technological opportunities, previous research including documented solutions to similar problems, and stakeholder interests and opinions.

Should requirements be formulated in terms of a solution?

Short answer: No

Long answer: Consider the following two requirements for an electronic health record system:

1 Physicians should be able to search for health records based on any patient characteristic
2 Physicians should be able to search for health records based on any patient characteristic using a relational database management system

Which requirement is to be preferred? The second one is more specific and, therefore, may seem to be preferable. However, this requirement restricts the designer to one single solution, a relational database management system, even if this would not be the best way of providing search capabilities to physicians. In general, including solutions in requirements formulations restricts the designer in devising the best possible solution. Therefore, requirements should not be expressed in terms of specific solutions.

6.2 Resources for Outline Artefact and Define Requirements

The results of the activity should always be based on and related to existing work. The researcher needs to report on previous research that has been carried out to solve similar problems, what artefacts have been designed and developed in that research, and what requirements have been addressed. Even if no other artefact has been designed previously to solve the same problem, or focus on the same requirements as in the current work, the researcher should still specify whether similar solutions exist and in what ways they differ from the proposed artefact. Thereby, the requirements will be given a context that supports both researchers and practitioners in assessing the originality and significance of the artefact.

Another basis for the activity consists of the interests and opinions of stakeholders. An investigation to determine these may include many different groups of stakeholders in one or several local practices. The stakeholders may hold differing opinions about the requirements, including their relative importance. Therefore, it is often worthwhile to ask the stakeholders to rank suggested requirements with regard to importance.

6.3 Research Strategies and Methods for Outline Artefact and Define Requirements

Research Strategies for Outline Artefact and Define Requirements

Surveys

Surveys can be used for eliciting requirements directly from stakeholders. They offer a relatively low-cost approach, in terms of time as well as other resources, to identifying requirements. Therefore, surveys make it possible to investigate the needs and wants of many people and different kinds of stakeholders, such as managers, employees, end-users, and customers. This comprehensive coverage increases the likelihood of finding all potentially relevant requirements and ensures that all stakeholder groups' voices are heard. However, there is a risk that surveys will result in incomplete requirements when stakeholders are not prepared to spend a sufficient amount of time and effort on providing information. Furthermore, the stakeholders may miss identifying requirements because they have limited knowledge or are biased in various ways. In other words, surveys as an instrument for requirements elicitation are dependent on the commitment, knowledge and interests of the stakeholders.

Case studies

Case studies can overcome some of the limitations of surveys for requirements elicitation. In particular, case studies offer opportunities for investigating stakeholder needs and requirements as well as their practice in greater depth over an extended period of time. Furthermore, a researcher can identify requirements even if a stakeholder does not explicitly state them. The deeper understanding provided by a case study and the reduced dependency on stakeholders can result in more complete and relevant requirements. However, case studies are time-consuming, their outcomes depend heavily on the competence of the researcher and they can also be biased by her interests and preconceptions. Furthermore, a case study is always carried out in a single local practice, which can limit the generalisability of the results.

Action research

The advantages and disadvantages of action research for requirements elicitation are similar to those of case studies. However, the dependence on the researcher is even greater in action research than in case studies, as she is to actively participate and intervene in a practice. There is a risk that she forces her own views on the stakeholders and comes up with requirements that are not particularly relevant for them. On the other hand, the researcher may be essential for suggesting requirements when her knowledge exceeds that of the stakeholders. This is often the case when a novel artefact is to be designed and introduced in a practice, and its stakeholders have only a limited understanding of the potential of the new artefact. The researcher can then inform and guide the stakeholders so that they become able to identify and articulate relevant requirements.

Theoretical analysis

In some situations, it may not be feasible to carry out empirical studies for eliciting requirements, and instead theoretical analysis has to be used. Such situations primarily occur when the artefact to be designed is truly novel, and it is still unclear how to use it in practice. A theoretical analysis may then suggest preliminary requirements based on possible usage scenarios. An obvious drawback of this approach is that it may become highly speculative and dependent on the competence, imagination and preconceptions of the researcher. Thus, the requirements identified through a theoretical analysis are usually not well-founded, but they can still function as a first step towards designing a highly novel artefact.

Research Methods for Outline Artefact and Define Requirements

Interviews

Interviews may be the most common method for gathering requirements. Interviews usually take a direct approach to requirements elicitation by asking stakeholders about features that they would like to see included in the outlined artefact and which explicit requirements they suggest. Interviews can be highly efficient and result in a large number of requirements in a short time. However, they may easily become stale and stifle creativity, which is obviously counterproductive for identifying requirements. To some extent, this problem can be reduced by using unstructured interviews that encourage the respondent to take more initiative. Another issue is that an interview may only be effective if the respondent is competent and applies sufficient time and effort, which may not always be the case. In addition to directly asking for requirements, interviews can be used for increasing the understanding of the respondent's practice as well as her attitude to the artefact under consideration.

Group discussions

Group discussions can overcome some of the disadvantages of interviews for direct requirements elicitation. When people meet, discuss and brainstorm in groups, the chances increase that more imaginative and creative requirements will be suggested. This is especially so if people with different backgrounds and competences are included in the same group; they will be able to surprise, inspire and encourage each other to come up with novel requirements. However, as always in group discussions, there is a risk that one or a few persons will dominate, which may reduce the willingness of others to offer suggestions for requirements. A moderator who makes sure that everyone gets a chance to contribute can mitigate this to some extent.

Questionnaires

Questionnaires have the same advantages and disadvantages as interviews but often to an even higher degree. Questionnaires are inexpensive to distribute, which makes it possible to get suggestions for requirements from many stakeholders. However, filling in a questionnaire does not invite much creativity, meaning that innovative requirements rarely can be expected. On the other hand, questionnaires can be effective for ranking the importance of requirements that have already been identified through other methods.

Observation studies

Observation studies can be used for getting a better understanding of the practice in which an artefact will be used, which can provide clues for additional requirements. In this way, observation is used as a means for a researcher to generate requirements herself. Observation studies are effective when it cannot be expected that the stakeholders themselves are able to generate all relevant requirements, typically because they have a limited understanding of the outlined artefact. The value of the requirements produced through observation studies relies heavily on the competence of the researcher.

Document studies

Document studies can complement other methods for requirements elicitation, or be an alternative when access to stakeholders is limited. Document studies can improve the understanding of the practice under consideration, which may provide clues for requirements, analogously to observation studies.

6.4 Guidelines for Outline Artefact and Define Requirements

- *Specify what artefact to build!* Specify the artefact type (construct, model, method, instantiation) and its general characteristics.
- *Formulate each requirement clearly!* Describe each requirement in a precise, concise and easily understandable way.
- *Justify each requirement!* For each requirement, explain why it is needed and relate it to the problem.
- *Be realistic but also original!* Ensure that it is realistic to develop an artefact fulfilling the requirements but also try to be original.

- *Specify the sources of the requirements!* Describe the literature and the stakeholders that have contributed to defining the requirements.
- *Describe how you have defined the requirements!* Explain what you have done to define the requirements, in particular how you have reviewed the stakeholders and research literature.

6.5 Properties for Generic Requirements

Most requirements on an artefact are situation specific, in particular those concerning its function. However, there are also a number of generic requirements that are relevant for almost any artefact, e.g. that it should be easy to use or have a modular design. This section introduces a set of properties that are useful when defining such generic requirements. Based on the distinction between construction and environment, the properties are divided into internal properties that describe the inner structure of the artefact, and external properties that describe the relationship between the artefact and its environment. Furthermore, the external properties are divided into usage properties that describe how the artefact works and is perceived in use situations; management properties that describe how the artefact is managed over time; and generic external properties that mainly describe how the artefact is structurally related to its environment.

The suggested properties can be used as inspiration for formulating generic requirements in an early stage of a design science project. They can also be used as validation support of already formulated requirements. Thereby important but missed requirements can be identified.

Internal Properties

Internal properties describe the inner structure of an artefact.

- *Coherence* - the degree to which the parts of an artefact are logically, orderly and consistently related. Coherence is low if an artefact includes parts that, in some sense, do not fit in with the rest of the artefact.

- *Consistence* (only for models) - the degree to which a model is free from conflicts.
- *Modularity* - the degree to which an artefact is divided into components that may be separated and recombined. Common requirements related to modularity are low coupling, that modules are not overly related with each other; high cohesion, that modules are highly related internally; and high composability, that modules can be easily replaced and recombined.
- *Conciseness* - the absence of redundant components in an artefact, i.e. components the functions of which can be derived from other components.
- *Elegance* - the degree to which an artefact is pleasing and graceful in appearance or style.

External Properties

External properties describe the relationships of an artefact to its environment, for example to users or other artefacts.

Usage

Usage properties describe how the artefact works and is perceived in use situations.

- *Comprehensibility* - the ease with which an artefact can be understood or comprehended by a user (also called understandability).
- *Learnability* - the ease with which a user can learn to use an artefact.
- *Usability* - the ease with which a user can use an artefact to achieve a particular goal.
- *Customisability* - the degree to which an artefact can be adapted to the specific needs of a local practice or user.

- *Suitability* - the degree to which an artefact is tailored to a specific practice, focusing only on its essential aspects (also called inherence or precision).
- *Accessibility* - the degree to which an artefact is accessible by as many users as possible.
- *Traceability* (only for methods) - the ability to verify the history of using a method by means of documentation.

Management

Management properties describe how an artefact is managed over time.

- *Maintainability* - the ease with which an artefact can be maintained in order to correct defects, meet new requirements, make future maintenance easier, or cope with a changed environment.
- *Flexibility* - the ease with which an artefact can be adapted when external changes occur (similar to maintainability; related notions are configurability, evolvability and extensibility).
- *Accountability* - the ease with which an actor can be made accountable for the workings of an artefact (a similar notion is auditability).

Generic

Generic properties mainly describe how the artefact is structurally related to its environment.

- *Expressiveness* (only for constructs and models) - the degree to which a set of constructs or a model is capable of representing the entities of interest in a domain.
- *Correctness* (only for models) - the degree to which a model corresponds to the domain it represents (also called accurateness).
- *Generality* - the degree to which an artefact is relevant not only for a local, but also for a global practice.

- *Interoperability* (only for instantiations) - the ability of an artefact to work together with other artefacts, in particular to exchange data (related notions are openness, compatibility and standards compliance).
- *Autonomy* (only for instantiations) - the capacity of the artefact to function without the involvement of another system.
- *Proximity* (only for models) - the degree to which independent aspects of a domain are captured by different constructs, and related aspects are represented by related constructs.
- *Effectiveness* - the degree to which an artefact is able to achieve its goals (a special case is completeness).
- *Efficiency* - the degree to which an artefact is effective without wasting time, effort or expense.
- *Robustness* (only for instantiations) - the ability of an artefact to cope with failures, errors and other problems during execution (related notions are degradability, survivability and safety).

6.6 Running Example

The second DIGIREAD activity was to outline an artefact and define the requirements. First the artefact was outlined. This meant deciding artefact type and the basic characteristics of the artefact. The research project came to the conclusion that a possible solution to the problem could be the introduction of a novel service that provides interactive and collaborative book reading using multimedia. Thus, the artefact was an instantiation in the form of a service, which will provide interactive and collaborative book reading using multimedia.

In order to define the requirements of the artefact, a survey of user needs was initiated. A focus group was set up to generate data, which included frequent book readers as well as non-readers. A usability and a social media expert also participated. The group met twice and produced an extensive list of possible requirements, most of which pertained to the functionality of the service. Emerging theories about social media were also investigated to help refine the identified requirements. Existing services for book sharing were studied, e.g. Amazon and Rethink Books. In order to prioritize the requirements, a questionnaire was distributed to the same people who had participated in the problem explication study. Examples of the most highly prioritized requirements for the service were:

- It should be possible to share book snippets over various channels (functional requirement)
- The owner of a book should be able to lend it to others using the service (functional requirement)
- It should be possible to read the first chapters of books for free (functional requirement)
- It should be possible to write and share book reviews independently of any book seller (functional requirement)
- The service should support searching and discovering books based on reviews (functional requirement)
- It should be possible to include other media, such as audio and video, in the text flow (functional requirement)
- It should be possible to move seamlessly between devices (environmental requirement, usability and interoperability)
- The service should integrate with social media services such as Facebook, Twitter and Google+ (environment requirement, interoperability)
- The service should be independent of platform and easy to adapt to mobile platforms such as Android and iOS (environment requirement, interoperability)
- The service should be easy to use (environment requirement, usability)

The Outline Artefact and Define Requirements activity is summarized in figure 6.2.

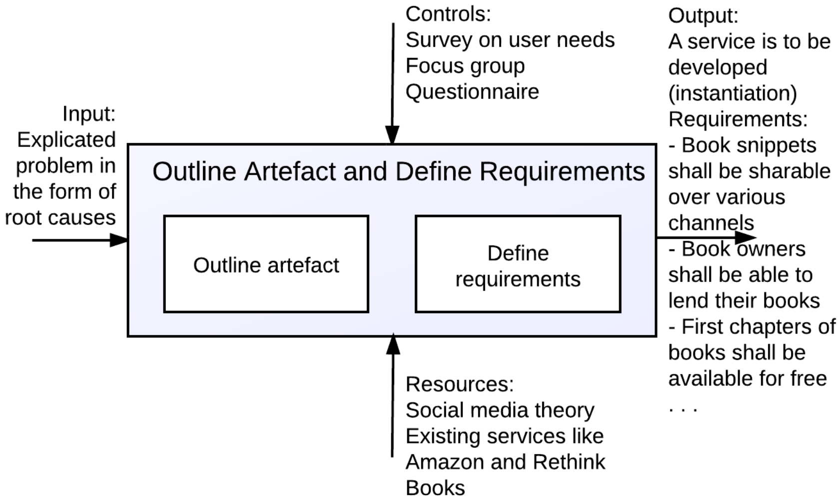

Figure 6.2 Outline Artefact and Define Requirements in the example

Further Reading

Requirements elicitation has for a long time been studied in the area of requirements engineering. An established textbook in the area was written by Sommerville and Sawyer (1997). A recent textbook on requirements engineering was written by Pohl (2010).

7 Design and Develop Artefact

The third activity of the method is Design and Develop Artefact, the goal of which is to create an artefact fulfilling the requirements derived from the previous activity. This includes designing both the functionality and construction of the artefact. In other words, the activity can be described as:

> Create an artefact that addresses the explicated problem and fulfils the defined requirements

The result of this activity will primarily be prescriptive knowledge, which can be embedded in the created artefact, see Section 2.2. Furthermore, the activity will produce descriptive knowledge about the design decisions taken and their rationale.

The activity Design and Develop can be structured and visualized using the IDEF0 technique, see figure 7.1. The input is an artefact outline and a set of requirements as provided by the previous activity. The output is an artefact fulfilling these requirements and knowledge about it. The resources used by the activity consist of knowledge from the research literature and other written sources as well as knowledge embedded in artefacts and assertions from relevant stakeholders. The controls can include research strategies and methods, and may also include any practice-based development approaches.

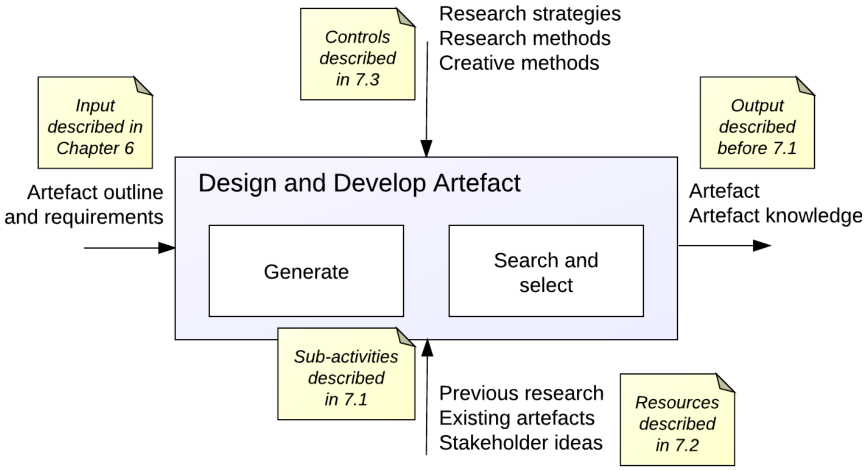

Figure 7.1 Artefact Design and Development

7.1 Sub-activities of Design and Develop Artefact

The activity Design and Develop Artefact includes two sub-activities. The first, Generate, produces new possible solutions, while the second one, Search and select, evaluates and selects from the generated solutions. Thus, Design and Develop Artefact can be viewed as a search process through a solution space (Simon, 1996). According to this view, the designer starts with setting up a solution space consisting of possible solutions and then pruning it. In practice, the sub-activities are carried out in parallel and iteratively.

Generate

Generating innovative and useful design solutions is to some extent always dependent on luck. However, as Louis Pasteur observed in 1854, "Chance only favours the prepared mind". The mind can become prepared through exploratory studies of potential users of the artefact in their practices, using action research, and ethnography as well as naturalistic observation.

There also exist several practice based approaches for solution generation. One of them is *empathetic thinking* in which a designer tries “to see the world through the eyes of others, understand the world through their experiences, and feel the world through their emotions” (Brown, 2009). Empathetic thinking can help to expand the designer’s mind, thereby supporting the creation of novel solutions. Another approach for generating solutions is de Bono’s *lateral thinking* (de Bono, 1973), who suggests a non-traditional way of reasoning. Instead of focusing on logical step-by-step arguments, de Bono suggests a spectrum of practices for generating fresh ideas including random generation, provocative generation such as wishful thinking and exaggeration, challenge generation where anything can be questioned, and disproval of generally accepted truths.

One established instrument for generating ideas in groups is *brainstorming*, where the participants aim to produce as many ideas as possible, attempt to withhold criticism, encourage new and unusual ideas, and try to integrate and improve ideas that have been proposed. Brainstorming is a generic instrument for idea generation that has been applied in many areas. For example, a goal of a brainstorming session could be to identify important activities in a method for managing risks in agile software development projects. First, the group could identify possible activities by trying to suggest and write down as many as possible without any criticism. The next step could be to eliminate duplicated activities or organise smaller activities into larger ones. Finally, the group can prioritise among the suggested activities in order to select the most useful ones, thereby moving to the search and select sub-activity.

In the area of IT and information systems, there are also several other more specialized instruments, like participative modelling, walk-throughs and pair design. *Participative modelling* resembles to some extent brainstorming but uses specific techniques for expressing ideas, such as goal, process and conceptual models. It also makes use of certain tools for visualization and cooperative model development, e.g. whiteboards, plastic sheets and post-its. A *walk-through* is a kind of peer review, where a designer leads members of a development team and other stakeholders through an artefact, for example a method. The participants may ask questions, point out problems, suggest alternative solutions, or provide feedback in any other form. *Pair design*, based on the agile practice of pair programming, is a way of working where two designers work together and simultaneously develop an artefact. Typically, one designer makes a design decision, e.g. introduces an activity into a method, and the other designer immediately reviews it and suggests possible improvements or potential problems. The instruments introduced here are certainly not exhaustive but they provide a representative sample of techniques used for supporting cooperative design work.

Search and Select

When a number of solutions have been generated, the designer makes a first design decision, thereby pruning away parts of the solution space. She continues and makes additional design decisions, which further narrows the space. The process goes on and can be viewed as a systematic exploration of the solution space. At each step the designer is guided in her decision making by some criteria and the requirements on the artefact. The guidance can sometimes take the form of a goodness or utility function, which can be used to determine which design decisions to make. Some authors have even argued that the search process can be more or less automated using AI techniques (Simon, 1996). Though this has not proved feasible, the view of design as a search process is useful in supporting the communication, documentation, planning and structuring of design work.

Generating solutions requires another kind of thinking than that needed for selecting from given solutions. The difference is sometimes expressed in the notions of convergent and divergent thinking. *Convergent thinking* in design aims at deciding among existing alternatives (sub-activity Search and select), while *divergent thinking* is about generating new alternatives from which to choose (sub-activity Generate). In other words, divergent thinking creates choices in a solution space and is highly innovative and imaginative, while convergent thinking makes choices, which can be more analytic and rational.

7.2 Resources for Design and Develop Artefact

Designing and developing an artefact is a combination of reusing and adapting components from existing solutions, inventing new components, and combining them in an innovative way. Therefore, related solutions need to be analysed by studying previous work, both in research literature and artefacts used in practice. Even if the artefact to be designed is highly original, the researcher should relate and compare it to existing solutions.

Another basis for this activity consists of ideas and opinions generated by stakeholders. While stakeholder input is almost always essential for defining requirements, its value for design and development is sometimes limited. Stakeholders may not be able to contribute if the artefact being designed has a highly complex construction. However, if the artefact has a simpler structure, experienced users may provide significant contributions, as witnessed by the phenomenon of Open innovation (Chesbrough, 2005).

Regardless of the resources used in creating a design, it is valuable to document the design rationale, i.e. a listing of and argumentation about the decisions made during the design process. A design rationale should contain the reasons and justifications behind design decisions, alternative decisions considered, and the arguments leading to the decisions. A design rationale can support communication during a single project, but it is also useful for facilitating reuse between different projects. In fact, a design rationale can be one of the most valuable outcomes of a design science project, as it will record the reasoning behind design decisions including potential pitfalls. This knowledge can be of great value to subsequent projects, in particular it may help them avoid dead ends and other kinds of problems.

7.3 Research Strategies and Methods for Design and Develop Artefact

Design and Develop Artefact differs from the other design science activities in that it does not primarily aim to answer questions by producing descriptive or explanatory knowledge. Instead, its main purpose is to produce prescriptive knowledge by creating an artefact. Therefore, research strategies and methods are less important here than in the other activities. However, this does not imply that research methods are without value for developing an artefact. On the contrary, interviews, observation studies and other data generation methods can be highly effective in producing ideas for design solutions. The point is rather that it is not critical that research methods are used for coming up with possible solutions; any approach for generating solutions is admissible as long as it works.

7.4 Guidelines for Design and Develop Artefact

- *Clearly describe each component of the artefact!* Describe both the functionality and construction of each artefact component.
- *Justify each component of the artefact!* Explain the purpose of each artefact component, in particular which requirement(s) it addresses.
- *Describe the use of the artefact!* Describe how the artefact and its components are intended to be used in its intended practice.
- *Clarify the originality!* Describe in what respects the artefact is different from existing ones with respect to both functionality and construction.
- *Specify the sources of the artefact design!* Describe the literature and the stakeholders that have contributed to components of the artefact and/or inspired the design of new components.

– *Describe how you have designed and developed the artefact!* Explain what you have done to design and develop the artefact, in particular how you have reviewed the stakeholders, existing solutions, and research literature.

7.5 Running Example

The third activity in DIGIREAD was to design and develop the artefact. This activity consisted of generating and selecting solutions.

The project first generated alternative solutions towards providing interactive and collaborative book reading using multimedia. This was done by designing a set of service functions, their user interface (UI) representations in the form of UI components and an overall architecture of the service. This was carried out by a small group of software engineers and the same usability expert who participated in the requirements definition activity. The group made frequent use of pair design to generate the service functions, the UI components and the architecture, and was closely intertwined with the requirements definition activity. As a knowledge base for the activity, the group made use of software engineering techniques and principles for service oriented architectures.

The second sub-activity was to select one of the alternative solutions generated, for further development. i.e., the service functions and user interface components. This was supported by peer reviews in the form of walk-throughs. The group decided to design a layered architecture for the service. The reason for this choice was improved flexibility and maintainability, though performance could suffer. The Design and Develop activity is summarized in figure 7.2.

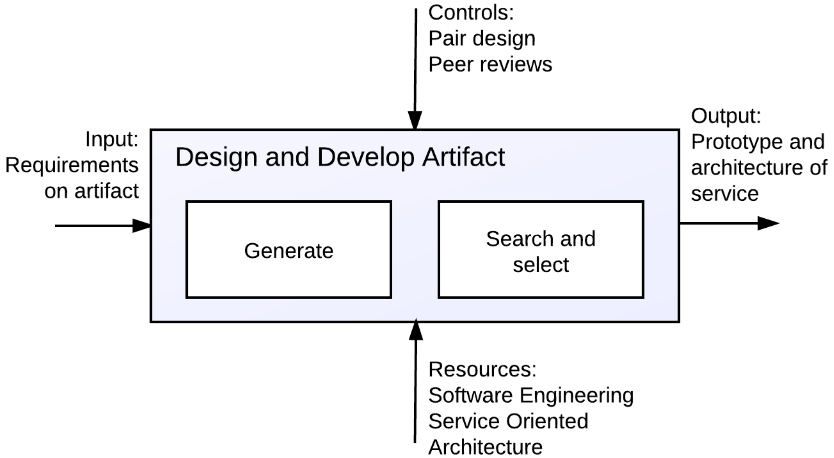

Figure 7.2 Design and Develop Artefact in the running example

Further Reading

Many good books exist on the art of designing artefacts, e.g. those written by Brown (2009) and Cross (2011), while a classical text is (Simon, 1996). The relationships between design, explanation and exploration are discussed by Gibbons and Bunderson (2005).

8 Demonstrate Artefact

The fourth activity of the method is Demonstrate Artefact, which aims to demonstrate the use of the artefact in one case, thereby proving its feasibility. In other words, the activity addresses the question:

> How can the developed artefact be used to address the explicated problem in one case?

The answer to this question will primarily consist of descriptive knowledge describing how the artefact works in one case, but also explanatory knowledge explaining why the artefact works.

A demonstration shows that the artefact in fact can solve some aspects of a problem in one illustrative or real-life case. A demonstration can be seen as a weak form of evaluation; if the artefact can solve some aspects of a problem in one case it might be able to do so in other cases as well. Furthermore, a demonstration can also help communicate the idea behind the artefact to an audience in a vivid and convincing way.

The activity Demonstrate Artefact can be structured and visualized using the IDEF0 technique, see figure 8.1. The input is an artefact provided by the previous activity. The output is a demonstrated artefact including information on the workings of the artefact in one case. The resources used by the activity consist of domain specific knowledge about the artefact and its environment. The controls will vary from case to case.

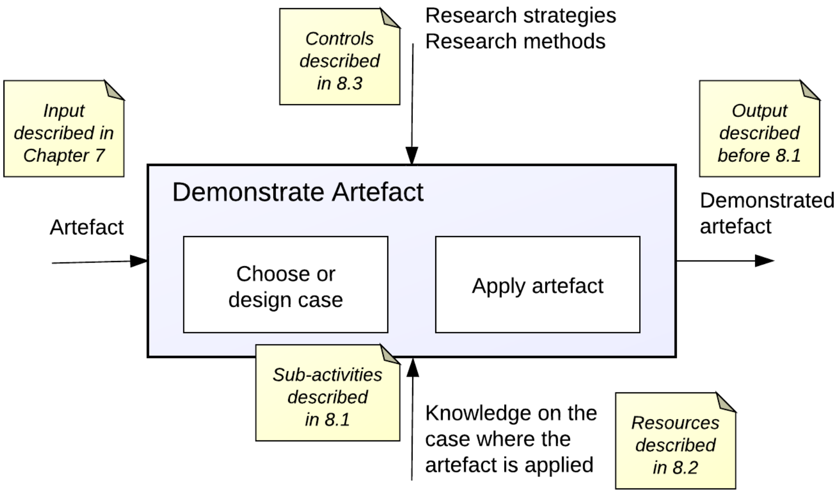

Figure 8.1 Artefact Demonstration

8.1 Sub-activities of Demonstrate Artefact

The first sub-activity is to choose or construct a case on which to apply the artefact. This case can be a fictitious one developed by the researchers who designed the artefact, a well-documented case from literature, a real life case, or a combination of these. Cases from real life typically provide better external validity, but fictitious cases can sometimes be preferable as they can be designed to demonstrate the viability of the artefact under extreme conditions. The second sub-activity is to apply the artefact to the chosen case, which includes documenting the outcome of the application.

8.2 Resources for Demonstrate Artefact

The resource needed for this activity is primarily knowledge regarding the case in which to apply the artefact.

8.3 Research Strategies and Methods for Demonstrate Artefact

A research strategy is decided depending on the case chosen and the characteristics of the artefact. Clearly, action research and case study are natural choices when a real life case is used. Experiments are useful for fictitious as well as literature cases.

8.4 Guidelines for Demonstrate Artefact

- *Justify the choice of case!* Explain why the chosen case is representative of the problem and challenging enough to offer an adequate test bed.
- *Make clear how much of the artefact is tested!* Describe the components and aspects of the artefact that are actually used in the demonstration.

8.5 Running Example

The demonstration of the designed and developed service for interactive and collaborative book reading in the DIGIREAD project consisted of two sub-activities: choose or design a case and apply the artefact to the case.

The researchers decided to design a case in the form of an experiment. The case design included a number of tasks to be carried out by users, including writing reviews, sharing book snippets via Twitter, discovering new books based on reviews, and switching between reading and listening to the same text.

Ten presumptive users then carried out the experiment over the course of a day. The users were given access to a prototype of the service, which provided more than 90% of the required functionality and included approximately 100 books. The users carried out the tasks described above and the researchers then logged all service interactions and analysed them using quantitative methods. The experiment functioned as a proof-of-concept showing that the service could actually be used as intended. The Demonstrate Artefact activity is summarized in figure 8.2.

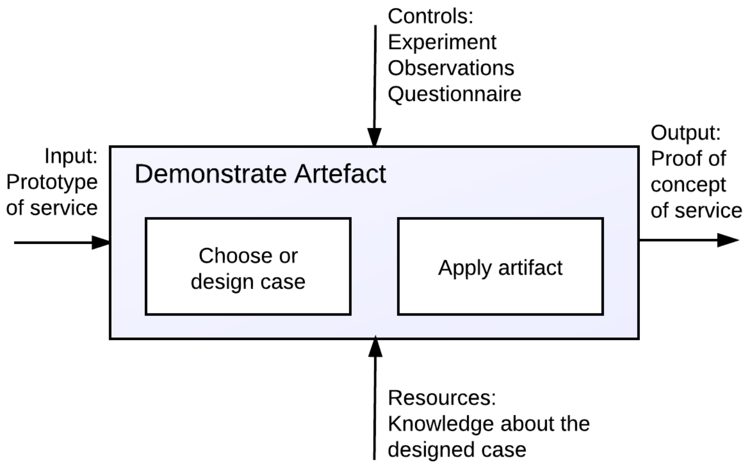

Figure 8.2 Demonstrate Artefact in the running example

9 Evaluate Artefact

The fifth activity is Evaluate Artefact, which aims to determine how well the artefact is able to solve the explicated problem and to what extent it fulfils the requirements. In other words, the activity addresses the question:

> How well does the artefact solve the explicated problem and fulfil the defined requirements?

The answer to this question will primarily consist of descriptive knowledge, but may also include explanatory knowledge explaining why the artefact is able to solve the problem.

The activity Evaluate Artefact can be structured and visualized using the IDEF0 technique, see figure 5.1. The input is an artefact provided by the previous activity. The output is an evaluated artefact including information on how well the artefact works and why. The resources used depend on the evaluation strategy and can include experts as well as sites for case studies or action research. The controls can include any research strategy or method that can be used for evaluation.

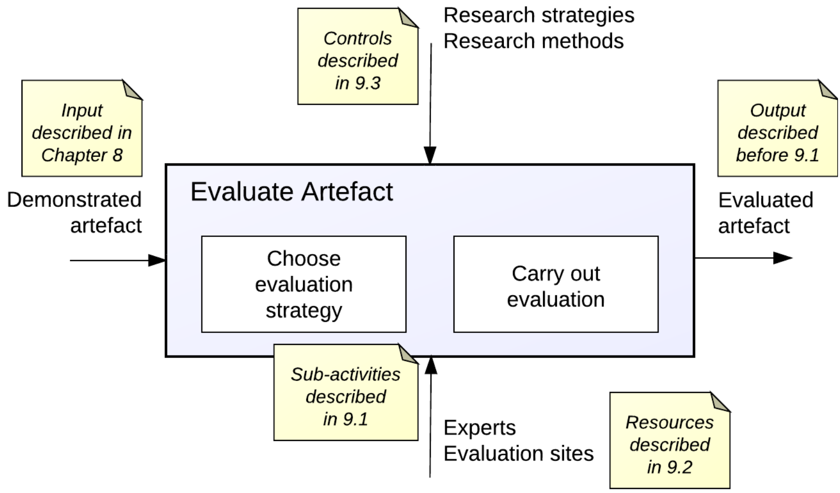

Figure 9.1 Evaluate Artefact

9.1 Sub-activities of Evaluate Artefact

The activity Evaluate Artefact includes two sub-activities. The first, Choose evaluation strategy, determines how the evaluation is to be carried out, while the second, Carry out evaluation, actually performs the evaluation.

Choose evaluation strategy

There are two main strategies: ex ante and ex post evaluation. Ex ante evaluation means that the artefact is evaluated without being used, while ex post evaluation requires the artefact to be employed.

An ex ante evaluation often makes use of interviews, where experts express their views on an artefact. The experts base these views on their general knowledge as well as experience of similar artefacts and their applications. For some requirements, e.g., modularity and coherence, an ex ante evaluation can provide both valid and reliable results. For other requirements, e.g., usability and effectiveness, the views of the experts can be rather speculative. In general, the main drawback of an ex ante evaluation is its heavy reliance on the subjective judgments of experts, while the main benefit is its low cost.

An ex ante evaluation sometimes consists of arguments provided by the researchers who developed the artefact. In this case, they evaluate it by reasoning and arguing that it fulfils the defined requirements and can solve the explicated problem. This form of evaluation is sometimes called *informed argument.* A common line of reasoning using informed argument is to claim that the artefact fulfils a requirement because it has a certain construction. For example, it can be argued that a new MMORPG is easy to learn because its interface is similar to that of World of Warcraft. Informed argument is obviously a weak form of evaluation, as it may easily be biased by the backgrounds and interests of the researchers. However, informed argument is inexpensive and is often used when evaluating highly innovative and still immature artefacts. Researchers may use informed arguments at informal presentations or research workshops. Based on feedback from other researchers, the artefact can then be refined before a stronger form of evaluation is carried out.

While ex ante evaluations are often weak, ex post evaluations can be considerably stronger. Such evaluations require that an artefact is actually put into operation before being evaluated. In contrast to ex ante evaluations, an ex post evaluation can preferably be employed to evaluate the usability of an artefact including its comprehensibility and learnability. Ex post evaluations are also appropriate for investigating the effects an artefact may have on its environment, e.g. how a new ERP system may influence the power relationships in a workplace.

A main benefit of ex post evaluations is, as mentioned above, that they can be employed to evaluate the usability and effects of artefacts. Their main drawback is the low internal validity when an artefact is employed in a complex environment, such as an organisation. In such a case, it can be next to impossible to distinguish the influences of the artefact from those of contingent factors. For example, the alleged effects of an ERP system on power relationships may instead be due to an economic crisis, other change projects, new employees, or other factors.

Carry out evaluation

The evaluation is to be carried out and documented according to the requirements of the selected research strategies and methods. In particular, the validity and reliability of the evaluation are to be discussed.

9.2 Resources for Evaluate Artefact

For ex ante evaluations, the most important resource is a number of experts who should have competence as well as the time and willingness to evaluate the artefact. Obviously, these requirements may need a trade-off, as the most qualified experts typically are the busiest ones. Ex post evaluations often require one or several sites where the artefact can be employed. Getting access to such sites can be challenging, for example when a new IT system is to be evaluated in an organisation.

9.3 Research Strategies and Research Methods for Evaluate Artefact

Research Strategies for Evaluate Artefact

Surveys

Surveys can be used for gathering feedback on an artefact from a large number of stakeholders and experts. Therefore, the results of a survey have fair chances of being generalizable, provided that sampling and data analysis have been carried out in a rigorous way. However, a drawback of surveys is that they often only result in shallow responses from respondents, as they may not be prepared to spend much time and effort on answering survey questions.

Experiments

Experiments are popular instruments for evaluating an artefact, as they allow a researcher to achieve high internal validity by carefully controlling the conditions under which an experiment is carried out. On the other hand, external validity can suffer, since the artificial setting of the experiment can be decidedly different from the practice in which the artefact is to be used.

Case studies

Case studies allow a researcher to make a deep evaluation of an artefact and understand the reasons for its success or failure, at least in one case. This understanding can aid the researcher in coming up with improved redesigns of the artefact, which can be used in an iterative development process. However, case studies require much effort and their outcomes depend heavily on the competence and experience of the researcher. They can also be biased by her interests and preconceptions. Furthermore, carrying out a case study on only a single site can limit the generalizability of the results.

Ethnography

The research strategy ethnography allows a researcher to understand not only how a practice influences the use of an artefact, but also how the artefact may change the practice. Therefore, the researcher may identify interplays between artefact and practice that might not be apparent to its participants. A drawback of ethnography is that it is time-consuming and requires highly qualified researchers to be effective.

Theoretical Analysis

Theoretical analysis can be used to verify that an artefact fulfils requirements on internal properties, like coherence and consistence. Theoretical analysis, in the guise of informed arguments, can also be used to show that less formal requirements are fulfilled. Informed arguments typically start from the construction of an artefact and then argue that these ensure that some requirement is satisfied.

Research Methods for Evaluate Artefact

Interviews

Interviews are effective instruments for gathering stakeholder opinions and perceptions about the use and value of an artefact. Interviews also allow a researcher to delve deeper into stakeholder views, as she can ask follow-up questions when needed. However, results from interviews are always dependent on the perspective and competence of the respondent, which must be taken into account when interpreting interview answers. Furthermore, respondents usually want to be nice and polite when meeting a researcher in person and assessing her results, meaning that they may withhold criticism and express more positive views than they actually hold.

Questionnaires

Questionnaires can be highly efficient for gathering the opinions and perceptions of many stakeholders about an artefact. However, the answers are often superficial and do not allow a researcher to gain a deep insight into the views of individual respondents.

Observation studies

While interviews and questionnaires are effective tools for understanding the subjective views and perceptions of stakeholders, observations offer researchers an instrument for a more objective evaluation. For example, an interview can reveal whether or not some respondents perceive a new information service as easily learnable. However, perceived learnability should not uncritically be equated with learnability. Observations may very well show that the service is not easily learnable even though the respondents perceive it so, or vice versa.

9.4 Guidelines for Evaluate Artefact

- *Evaluate every requirement!* Every requirement identified in the activity Outline Artefact and Define Requirements shall be evaluated.
- *Evaluate how the artefact can solve the problem!* Investigate not only how well the artefact fulfils the requirements but also to what extent it can address the problem.
- *Describe how you have evaluated the artefact!* Explain what you have done to evaluate the artefact, in particular how you have studied stakeholders using the artefact.

9.5 Ethical Consequences

Evaluation of an artefact's effects, as discussed so far, has focused solely on the intended effects of using the artefact. However, unintended effects also need to be considered, in particular when investigating the ethical consequences of an artefact and its use. Ethical investigations can be carried out in many different ways and can be based on both utilitarian and deontological theories. Even if there is no single best way to investigate the ethical aspects of artefact use, it is still meaningful to ask for practical guidelines that can assist in this task. The remainder of this section outlines a deontologically based approach that can support a designer in identifying the ethical consequences of artefact use.

The first step of the approach aims at finding individuals and groups of people that can be affected by the use of an artefact. This can be done by first identifying all the practices that are influenced by the artefact. This would not only include the intended practice, see section 1.3, but also other practices, where the use of the artefact may cause various side effects. Within each practice, individuals and groups that can be affected are identified.

The next step is to investigate, for each individual and group, in which respects it can be affected. This can certainly be done in many different ways, where one is to consider basic human rights and determine how they can be influenced by the artefact use. A recent proposal for the most fundamental human rights has been formulated by Martha Nussbaum in the form of a list of central human capabilities. Nussbaum's capability approach is based on the view that ethical values should focus on human functioning, i.e. what people do or are able to do. This is in contrast to utilitarian approaches that focus on human preferences, i.e. what people prefer to do. Nussbaum argues that the latter are unstable and easily distorted, implying that human functioning is a safer ground for ethical values. Nussbaum (2007) offers a tentative list of central human capabilities.

"1. Life. Being able to live to the end of a human life of normal length; not dying prematurely, or before one's life is so reduced as to be not worth living.

2. Bodily Health. Being able to have good health, including reproductive health; to be adequately nourished; to have adequate shelter.

3. Bodily Integrity. Being able to move freely from place to place; to be secure against violent assault, including sexual assault and domestic violence; having opportunities for sexual satisfaction and for choice in matters of reproduction.

4. Senses, Imagination, and Thought. Being able to use the senses, to imagine, think, and reason-and to do these things in a "truly human" way, a way informed and cultivated by an adequate education, including, but by no means limited to, literacy and basic mathematical and scientific training. Being able to use imagination and thought in connection with experiencing and producing works and events of one's own choice, religious, literary, musical, and so forth. Being able to use one's mind in ways protected by guarantees of freedom of expression with respect to both political and artistic speech, and freedom of religious exercise. Being able to have pleasurable experiences and to avoid nonbeneficial pain.

5. Emotions. Being able to have attachments to things and people outside ourselves; to love those who love and care for us, to grieve at their absence; in general, to love, to grieve, to experience longing, gratitude, and justified anger. Not having one's emotional develop-

ment blighted by fear and anxiety. (Supporting this capability means supporting forms of human association that can be shown to be crucial in their development.)

6. Practical Reason. Being able to form a conception of the good and to engage in critical reflection about the planning of one's life. (This entails protection for the liberty of conscience and religious observance.)

7. Affiliation. A. Being able to live with and toward others, to recognize and show concern for other human beings, to engage in various forms of social interaction; to be able to imagine the situation of another. (Protecting this capability means protecting institutions that constitute and nourish such forms of affiliation, and also protecting the freedom of assembly and political speech.) B. Having the social bases of self-respect and nonhumiliation; being able to be treated as a dignified being whose worth is equal to that of others. This entails provisions of nondiscrimination on the basis of race, sex, sexual orientation, ethnicity, caste, religion, national origin.

8. Other Species. Being able to live with concern for and in relation to animals, plants, and the world of nature.

9. Play. Being able to laugh, to play, to enjoy recreational activities.

10. Control over One's Environment. A. Political. Being able to participate effectively in political choices that govern one's life; having the right of political participation, protections of free speech and association. B. Material. Being able to hold property (both land and movable goods), and having property rights on an equal basis with others; having the right to seek employment on an equal basis with others; having the freedom from unwarranted search and seizure. In work, being able to work as a human being, exercising practical reason and entering into meaningful relationships of mutual recognition with other workers."

In order to identify and document the ethical consequences of artefact use, a designer can fill in a table like the one in figure 9.2. For each group or individual and each capability, the designer is to determine the effects of the use of the artefact.

Capabilities	Group1	Group 2	Group 3	....
Life				
Bodily health				
Bodily integrity				
Senses and thought				
Emotions				
Practical reason				
Affiliation				
Other species				
Play				
Environment control				

Figure 9.2 Capability based template for ethical analysis

9.6 Running Example

The fifth DIGIREAD activity was to evaluate the designed and developed artefact. An ex ante evaluation strategy was chosen, i.e. the artefact was evaluated without being used.

The ex ante evaluation of the artefact was then carried out, in which experts with different competences participated. Three experts were interviewed, one from the area of social media, one from usability and one from software engineering. A semi-structured interview of about 45 minutes was carried out with each expert. The interviews were video recorded and then independently analysed by two members of the research team. The evaluation was based on the defined requirements of the artefact. The main outcome of the evaluation was a concern about usability, as the proposed artefact could be highly complex.

In addition to the expert interviews, the researchers also provided informed arguments as a part of the evaluation. These arguments primarily showed that the construction of the artefact ensured that the functional requirements were at least partially fulfilled. Furthermore, it was argued that the proposed architecture should provide adequate interoperability. The Evaluate Artefact activity is summarized in figure 9.3.

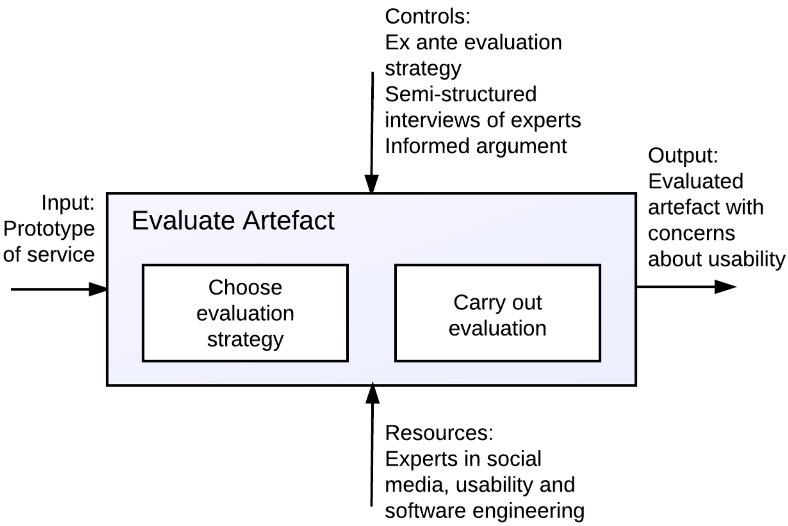

Figure 9.3 Evaluate Artefact in the running example

Further Reading

A great deal of literature exists on evaluation in various domains. For Human Computer Interaction a comprehensive introduction in the form of a presentation is given by Dix (2009). The evaluation of models and methods in information systems is discussed by Moody (2003; 2005). Clements et al. (2001) investigate the evaluation of software architectures. Pries-Heje et al. (2008) discuss the distinction between ex ante and ex post evaluations in design science research. The box above on design theory is based on the work by Walls et al. (2004) and Gregor and Jones (2007).

10 Communicate Artefact Knowledge

Design science results are typically to be communicated to research as well as practitioner communities, which may include both technology-oriented and management-oriented audiences. Furthermore, some design science results can be of such a broad interest that they are worthwhile to communicate to the general public.

Communicating results to researchers requires attention to rigour so that they can evaluate the results and build on them in future work. In particular, the knowledge base should be carefully described as well as its relationship to the results produced. The choice of research strategies and methods should be well justified. The application of the chosen research strategies and methods should also be described in detail including discussions on validity and reliability.

These concerns about methodology and related research are less relevant for communication to practitioners. The focus is then rather on problem and practice as well as concrete outcomes in terms of construction, function, usability and effects.

Technology-oriented audiences benefit from extensive details on the construction of an artefact, i.e. its components and their relationships. This allows practitioners to construct and implement the artefact in a practice, and researchers to further develop the artefact.

Management-oriented audiences are primarily interested in the problem the artefact addresses, what benefits it can bring to a practice, how easy it is to use, and its overall effects, e.g. on efficiency and agility in an organisational setting. Knowledge about these aspects will enable managers to determine whether or how to apply the artefact. The construction of the artefact is less relevant, though managers will still need a basic knowledge of the inner workings of the artefact in order to appreciate its significance and understand its application. When communicating to the public, the main focus is often on the effects of a novel artefact, including its ethical and societal consequences. The interests of different audiences are graphically illustrated in figure 10.1.

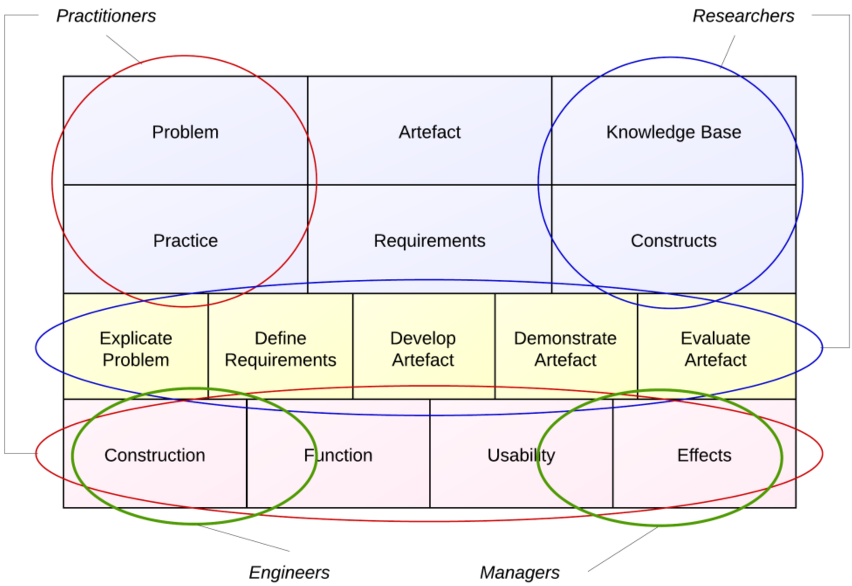

Figure 10.1 Different interests for different audiences

When disseminating design science results, the researcher has to select the right communication channels depending on the target. For research communities, results are primarily communicated through academic journals, conferences and workshops. Workshops often accept immature work and provide a forum for feedback and discussion about preliminary results, while journals mainly publish mature work that includes careful evaluation. For practitioner communities, research results can be communicated through trade fairs, white papers, magazine articles, blogs, etc. Regardless of the target of the communication, it is valuable to present results in a clear and easily understandable structure. For example that provided by the design science method as depicted by the IDEF0 diagrams and the design science canvas. This structure is in many respects also similar to the IMRAD (Introduction, Methods, Results And Discussion) structure, which is frequently used for organising empirical research papers.

Is design theory the same as design science?

Short answer: No

Long answer: In this book, design science has been presented as a knowledge building endeavour, which can be carried out according to the design science method presented in Chapters 4 to 9. In contrast, a design theory focuses on the results of the design science activities and shows how these can be structured. A design theory consists of a number of interrelated components that describe abstract artefacts like models and methods (each component is here exemplified using Codd's relational database theory):
Purpose and scope. The set of requirements or goals that specifies the type of artefact to which the theory applies and in conjunction also defines its scope and boundaries. (Improved database technology is needed for increasing productivity as existing approaches of managing data persistence are failing.)

Constructs. Representations of the entities of interest in the theory. These entities can be physical as well as abstract. (Attribute, tuple, n-ary relation, domain of values.)

Principle of form and function. The abstract blueprint or architecture that describes an artefact. For a model, its components and their relationships and functions would be described. For a method, its steps and their order and purpose would be given. (A relation is defined over a domain of values and includes attributes and tuples.)

Artefact mutability. The changes in state of the artefact anticipated in the theory, that is the degree of artefact change encompassed by the theory. (The relational model allows for easy adaptation and change to base tables, while user views appear unchanged.)

Testable propositions. Testable propositions about instantiations of the artefact under consideration. Typically, these propositions state that if a model or method is instantiated then it will work, or it will have certain characteristics. (A relational database can perform as well as a non-relational database.)

Justificatory knowledge. The underlying knowledge or theories that provide a basis and justification for the design. (Set theory and behavioural science about human cognitive processes.)

Principles of implementation. Processes for implementing, i.e. instantiating, the artefact to which the theory applies (model or method) in specific situations. (Guidelines on how to create a relational database through normalization procedures.)

Expository instantiation. An implementation of the artefact that can assist in representing the theory both as an expository device and for purposes of testing. An instantiation can support communication about the artefact of a design theory. (A working relational database with tables filled with data.)

While the design science method focuses on organising research activities, a design theory aims at structuring the knowledge about an artefact. However, they are closely related in the sense that applying the design science method should result in a design theory. The *Explicate Problem* and *Define Requirements* activities should result in defining the purpose and scope of the design theory. The *Design and Develop* activity should identify the constructs and specify the form and function of the artefact. Testable propositions should be deduced by the *Evaluate Artefact* activity, and an expository instantiation should be shown by the *Demonstrate Artefact* activity. Justificatory knowledge is to be addressed by all the activities of the design science method. Artefact mutability and principles of implementation can also be addressed by several activities.

Further Reading

An established and easy to read textbook on scientific communication was written by Booth et al. (2008). Sörensen (2005) has written an entertaining paper on how to and how not to write scientific articles. Dixit (2011) has provided a concise introduction to the IMRAD format.

11 The Design Science Method and Systems Development

A quick look at the design science method may suggest that it is nothing more than yet another version of the traditional waterfall model for software development. The waterfall model is a sequential design process, where progress is viewed as a steady flow downwards in a number of consecutive phases, see figure 11.1.

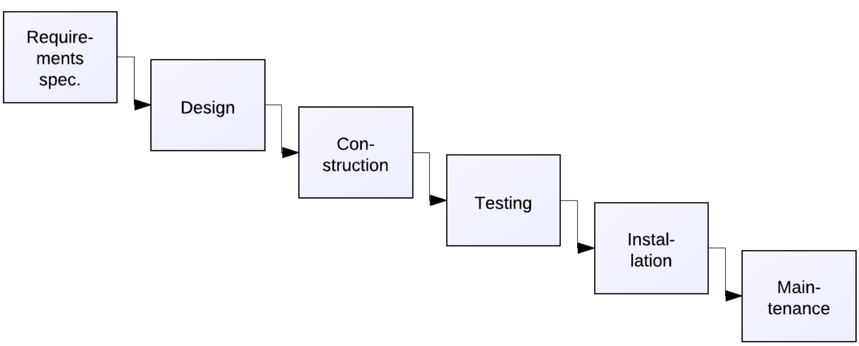

Figure 11.1 The Waterfall Model

The results produced in one phase are handed over as input to the next phase, meaning that a phase can only be started if the previous phase has been fully completed. The phases in different versions of the waterfall model may vary, but typically include requirements specification, design, construction, testing, installation, and maintenance.

The waterfall model has been heavily criticized for being inadequate for guiding large software projects in unstable environments. In an early stage of the software development process it is often impossible to define precise and complete requirements. In such situations, rapid prototyping is an essential tool for eliciting requirements from stakeholders. By creating and testing prototypes of the software to be developed, stakeholders will improve their understanding and be able to articulate more exact and relevant requirements. Thus, there may be many short iterations between specification of requirements, design, construction, and testing. For example, based on some stakeholders' requirements, a first draft of a prototype is designed, constructed and tested. The results of the test will spur new or refined requirements, which will be the start of a new iteration with a refined design of the prototype, followed by additional tests. The result of the tests will give rise to new and refined requirements, which start another iteration, and so on, see figure 11.2. Furthermore, the environment may change during the development process, e.g. due to technological developments or government regulations, which implies that there may be a need to iterate all the way back to requirements specification. Thus, the development process is highly iterative as it needs to obtain complex requirements and manage a changing environment.

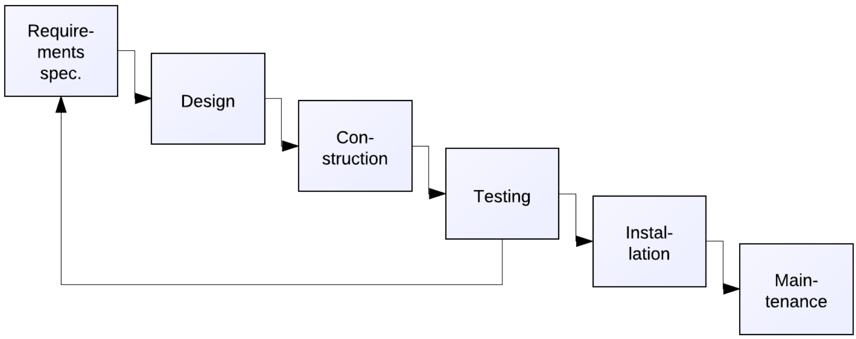

Figure 11.2 A Waterfall Model with a simple iteration

11.1 Temporal and Logical Groupings of Work

As the design science method may look very much like a sequential design process, see figure 4.1, it could be argued that it suffers from the same weaknesses as the waterfall model. In other words, it could be claimed that the design science method does not cater for vague requirements, changing environments, shifting stakeholder interests, unclear problem situations, etc. If this were true, the method would clearly not be of much interest. However, the method does not prescribe a sequential way of working. The activities are not to be seen as temporal groupings of work to be performed in sequence, but instead as logical groupings of work. Thus, the arrows in figure 4.1 should not be interpreted as temporal orderings but as input-output relationships. These interpretations can be made clearer by placing them in the context of the RUP (Rational Unified Process) framework.

RUP is structured in two dimensions, phases and disciplines, that capture the serial and iterative aspects of software development, respectively, see figure 11.3. The phases represent the sequential stages that a project traverses over time, while the disciplines correspond to the logical activities that are carried out during a project. RUP identifies four phases: inception, elaboration, construction, and transition. The inception phase aims at achieving consensus among the stakeholders about the objectives of the project; the elaboration phase specifies requirements in detail and outlines an architecture for the system to be built; the construction phase focuses on developing the system so that it is ready for deployment; and the transition phase delivers the system into production.

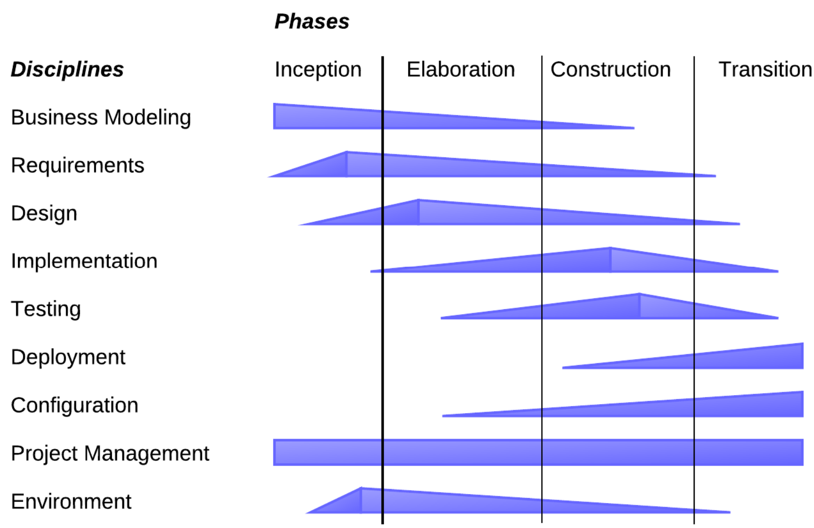

Figure 11.3 Disciplines and phases in RUP

While the phases capture the serial aspects of a project in RUP, the disciplines address the iterative aspects. During each phase, the software developers will alternate between (almost) all of the disciplines. For example, during the inception phase the developers will typically address a subset of the requirements, carry out some business modeling, return to the requirements and revise them, suggest an initial design, once again revise the requirements, do some coding and preliminary tests, and then improve the design. Furthermore, the inception phase can be broken down into several iterations, each of which only addresses a small portion of the system to be built, thereby making RUP even more iterative. thereby making RUP even more iterative. Similarly, all the other phases will also include several disciplines.

The relationships between phases and disciplines are shown in figure 11.3, which is sometimes called a "hump chart". The humps for each discipline display how much effort that is spent on that discipline in the various phases. For example, the diagram shows that most of the work on requirements is carried out in the inception and elaboration phases, but it continues all the way into the transition phase. The sizes and placements of the humps may certainly vary from project to project and can be tailored as required.

Figure 11.4 shows a version of the hump chart, which is close to a waterfall model requiring that, for example, all work on business modeling and requirements be completed before any work on design can be started.

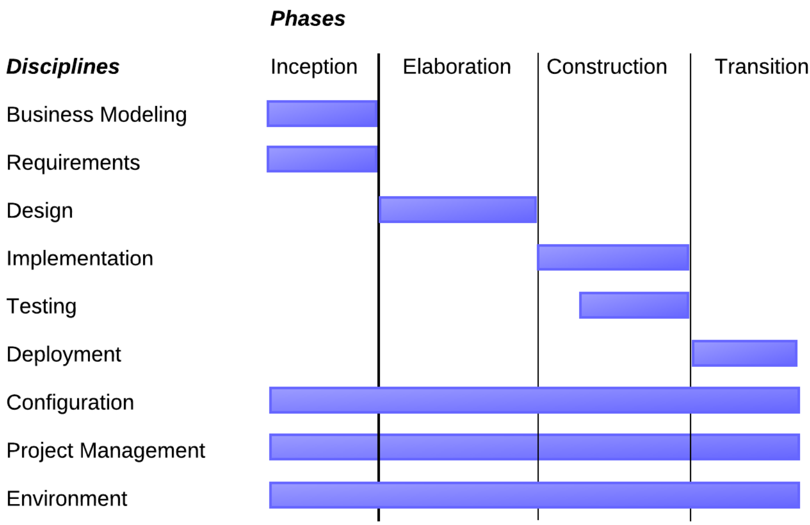

Figure 11.4 A Waterfall version of RUP

Another version of the hump chart is given in figure 11.5, requiring that all disciplines are given equal attention in all phases. This kind of diagram would reflect an extremely agile development process.

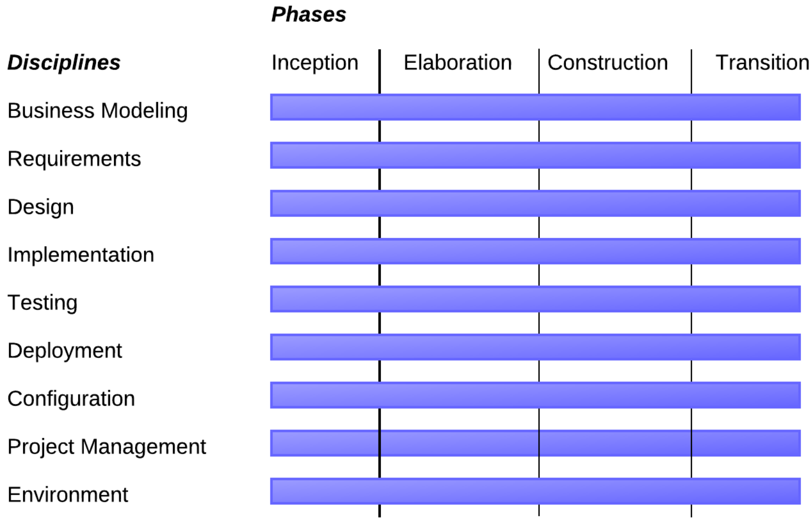

Figure 11.5 An Agile version of RUP

Returning to the design science method, its activities are analogous to the disciplines of RUP, not the phases. In other words, the activities are not to be sequentially ordered in time but can be performed in parallel and in any order. The activities only tell what tasks need to be done in the method, what input they consume, and what output they produce. The activities are logical groupings, not temporal ones.

Design and Appropriation

People often adapt and use artefacts in ways that their designers never intended. For example, email was designed to support communication between people, but it is nowadays regularly used by people to send reminders to themselves or to store safety copies of documents. Dix (2007) describes this process of technology adaptation as follows:

"These improvisations and adaptations around technology are not a sign of failure, things the designer forgot, but show that the technology has been domesticated, that the users understand and are comfortable enough with the technology to use it in their own ways. At this point we know the technology has become the users' own not simply what the designer gave to them. This is *appropriation*."

Designers should be aware that the artefacts they create may be appropriated in unanticipated ways. They could even try to design in order to facilitate appropriation. Dix (2007) suggests a number of guidelines for this, three of which are:

Allow interpretation – "Don't make everything in the system or product have a fixed meaning, but include elements where users can add their own meanings."

Provide visibility – "Make the functioning of the system obvious to the users so that they can know the likely effects of actions and so make the system do what they would like."

Support not control – "As a designer you want to do things right, to make them as efficient and optimal as possible. However, if you optimise for one task you typically make others more difficult. In some situations, such as very repetitive tasks, then designing explicitly for the task may be the correct thing to do, perhaps taking the user step by step through the activities. However, more often the tasks description is incomplete and approximate, in particular ignoring exceptions. Instead of designing a system *to do* the task you can instead design a system so that the task *can be done*."

11.2 Differences between DS and Systems Development

Comparing the activities of the design science method to the disciplines of RUP, they look quite similar. Explicate Problem is similar to Business Modelling, Outline Artefact and Define Requirements is similar to Requirements, and so on. This observation holds not only for RUP but also for many other systems development methods. Thus, some new questions arise: Is the design science method not redundant? Could it not be replaced by some systems development method? Why introduce a new kind of process when RUP is there? The answers to these questions depend on the different purposes of design and design science, which were already introduced in Chapter 1.

The purpose of design is to create an artefact that fulfils the needs and requirements of some stakeholders, possibly only for a local practice. Design science, in contrast, aims at producing and communicating new knowledge that is relevant for a global practice. These differences in purpose give rise to three additional requirements on design science.

First, the purpose of creating new and generalizable knowledge requires design science projects to make use of rigorous research strategies and methods. Such methods are essential for creating results that can be critically discussed, evaluated, and validated. A possible objection to this line of reasoning is that many systems development methods already include tools and techniques that are quite similar to research methods, e.g. techniques for interviews or participative requirements elicitation. It is true that some of these tools and techniques are closely aligned with established research methods, but not always as they only aim at producing effective solutions, not knowledge for global practices. Thus, the design researcher needs to determine whether the tools and techniques offered by a systems development method are indeed sufficient for the purpose of producing knowledge, or whether additional research methods are required.

The second additional requirement on design science states that the results produced must be related to an existing knowledge base, thereby ensuring that they are both well founded and original. It is not sufficient just to produce some knowledge; it also has to be integrated with previous knowledge in the area and shown to provide novel insights.

Thirdly, the new knowledge should be communicated to both practitioners and researchers. This requirement on communication does not exist in most systems development methods, where instead there are activities devoted to deployment and maintenance.

In a project for developing an IT system, the design science method can be used in tandem with any systems development method. A typical scenario could look as follows. First, a systems development method is chosen. Second, the relevant parts (disciplines, workflows, tasks or whatever they may be called) of the chosen method are mapped to the activities of the design science method. Third, the tools and techniques used by the method are inspected in order to determine how closely they match adequate research methods. Fourth, the tools and techniques are adapted or complemented so that sufficiently rigorous research methods are used. Fifth, the work of the project is carried out in accordance with the chosen systems development method as well as the selected research methods. In parallel, the project will include work to relate the results to an existing knowledge base. Finally, the results will be communicated to relevant audiences. Thus, the project will primarily be governed by the chosen systems development method, but there will also be modified or additional activities for validating and communicating the knowledge produced.

Can companies use design science in their product development?

Short answer: Yes

Long answer: When companies need reliable knowledge about their customers, they can benefit from using design science. For example, if a company wants solid knowledge about the requirements of their customers, it can make use of research methods for requirements definition, including interviews and questionnaires. Likewise, if a company wants to understand how their customers perceive its products, research methods for evaluation can be relevant.

Some companies are well known for using research methods in their product development. One example is Google that regularly tests and evaluates its service offerings by means of advanced quantitative data analysis methods. Before a product launch, Google rolls out the new service to a limited number of users, collects data by recording their interactions with the service, and evaluates the records in order to improve it.

Caveat: The goal of companies is not to produce knowledge but to create value for their shareholders and other stakeholders. Thus, scientifically founded knowledge is never an end in itself for a company but only a means to other goals. In many cases, it is still worthwhile to use research methods to obtain reliable knowledge that can be used as a basis for decision making. However, research methods come with a cost, in particular in terms of time. For example, carefully evaluating a product before launching it takes valuable time, which may result in a competitor being first to market. Therefore, companies often deliberately choose to refrain from scientific investigations in order to improve speed and flexibility.

Further Reading

A textbook on methodologies for information systems development was written by Avison and Fitzgerald (2006). Kroll and Kruchten (2003) have written an easily readable introduction to RUP. Basic principles behind agile development were proposed by Beck and Beedle (2012).

12 Research Paradigms

A research paradigm is a set of commonly held beliefs and assumptions within a research community about ontological, epistemological, and methodological concerns. Such a paradigm constitutes a mental model that influences and structures how the members of a research community perceive their field of study. A research paradigm answers ontological questions about the nature of reality, what entities exist, and how these are related and interact with each other. A research paradigm also addresses epistemological questions about the ways in which people can know about reality, i.e. how they can gain knowledge about the world. Finally, a research paradigm answers methodological questions about legitimate ways of investigating reality and how to confirm that the knowledge generated is valid. Summarizing, ontology asks “What is in the world?”; epistemology asks “What can we know about the world and how should we obtain that knowledge?”; and methodology asks “Which procedures can be used to obtain knowledge?”.

The two most established research paradigms in the area of information systems are positivism and interpretivism. This chapter introduces these paradigms and discusses their relationship to design science, see also figure 12.1, which relates research paradigms to empirical research strategies and methods.

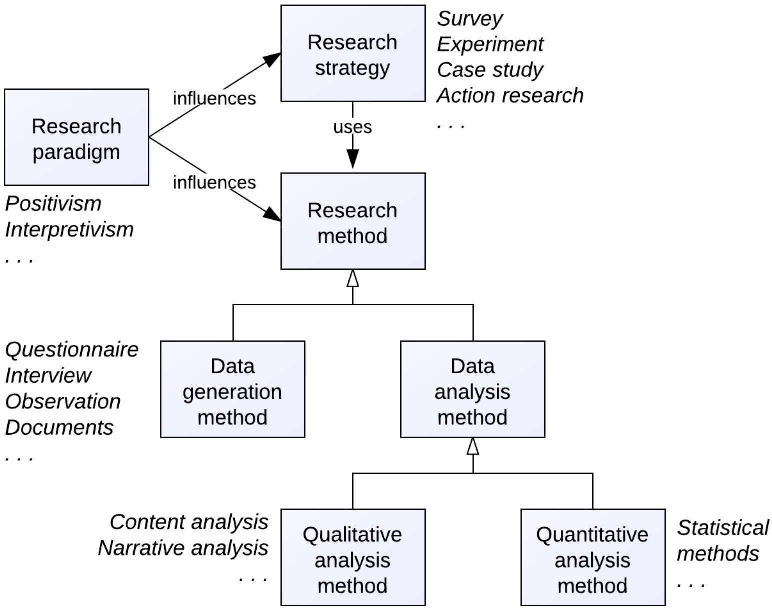

Figure 12.1 Research paradigms

12.1 Positivism

Positivism originated with the 19th century sociologist and philosopher Auguste Comte, who attempted to establish sociology as a science by applying a natural science view on social phenomena. Comte introduced positivism as a reaction to theological and metaphysical world views that embraced authority, divine revelation and tradition as legitimate knowledge sources. In contrast, positivism only accepts knowledge that is based on sense, experience and positive verification.

Ontologically, positivism assumes a reality that exists independently of human actions and experiences. As for natural science, the goal of social science should be to identify regularities among phenomena in the world and explain them through cause and effect relationships. Preferably, these regularities and explanations can and should be independent of context, i.e. they should be general and not depend on time, place or people.

Epistemologically, positivism claims that objective knowledge about the social world is obtainable, but only through observation and experimentation. Social inquiry should be objective, and a researcher should assume the role of a disinterested observer who is separate from the subjects being investigated. In other words, the researcher should keep at arm's length from the phenomena she studies in order to ensure that her background and interests do not bias her findings.

Methodologically, positivist researchers strive for an objective and value-free investigation where they distance themselves from the entities being studied. Preferred instruments for collecting research evidence are large quantitative studies including interviews and questionnaires. Experiments are also highly valued research strategies, as they can provide objective knowledge.

Positivism as described above may seem natural and commonsensical. However, this is exactly the problem with the positivist paradigm according to interpretivism. While positivism may be appropriate for natural science, interpretivists argue that it fails to capture essential aspects of the social world, in particular the subjective construction of social phenomena.

12.2 Interpretivism

Interpretivism emerged as a reaction to positivism at the beginning of the 20th century. One of its forerunners was the German sociologist Max Weber, who claimed that the social world, including social actions, can only be understood through grasping the subjective meanings and purposes that people attach to their actions.

Ontologically, interpretivism argues that in contrast to the natural world, the social world does not exist "out there", independent of human actions and intentions. Instead, the social world is constructed by people who carry out social actions and give meanings to them. For example, housing contracts are created through social actions involving two or more individuals, a national government, and possibly other actors. The meaning of such a contract is not given in advance but is determined by the actors who enter it. Furthermore, the meaning of the contract may change during its lifetime as negotiated by the actors involved. It may also be the case that the actors do not fully agree on the meaning of the contract but make their own different interpretations. In extreme cases, such disagreements may result in court trials where a third party, the court, decides how the contract is to be interpreted. This example illustrates that even such a straightforward social phenomenon as a housing contract is not part of a stable, objectively existing reality. Instead, it is constructed and continuously modified through the actions and interpretations of the actors who have an interest in it.

Any social phenomenon emerges as a result of the interactions and lived experiences of humans. This holds true for memberships in clubs, employment contracts, marriages, money, debts, holidays, religions, etc. All of these phenomena are created by people and their meaning depends on the actions, intentions and understanding of the individuals who participate in them. Thus, the social reality is much more elusive and fluid than the physical one, as it depends on people with all their whims, prejudices and other subjectivities.

The ontological differences between the natural and the social world have epistemological consequences. As social phenomena are grounded in the actions, experiences and subjective meanings of people, only superficial knowledge can be obtained by studying people like objects. Instead, a researcher should view people as subjects who actively create the social world. The researcher can only achieve a deep understanding of a social phenomenon by actively participating in that phenomenon together with the people who actually create it. She should not be a detached observer but rather try to become a member of the culture or group being studied by participating in their daily practices. In short, she needs to enter the shoes of the other. This is in stark contrast to the positivist ideal of separating the researcher from her object of study. Such a separation is selfdefeating according to interpretivism, as the subjective knower is a part and source of the social reality she knows.

Methodologically, interpretivist researchers prefer case studies, action research and ethnography, as these research strategies allow them to arrive at an empathetic or participatory understanding of social phenomena. The researchers can get close to the people who participate in the phenomena being studied and thereby come to understand their views and interpretations. However, this kind of methodology has been criticized for producing subjective research results, i.e. results that are highly dependent on the skills and experiences of the individual researcher. There is a risk that two researchers with different backgrounds and interests may arrive at very different results. One answer to this criticism is that an interpretivist researcher should always acknowledge her subjectivity and explicitly discuss how it could affect the validity of her results.

Positivism and Interpretivism in the Movies - Tim Burton's The Nightmare Before Christmas

As the arguments of interpretivism may seem somewhat abstruse on a first encounter, it can be helpful to make them concrete by putting them into some familiar context. One such context is provided by the 1993 stop motion movie *The Nightmare Before Christmas* produced by Tim Burton. The movie illustrates how difficult it is to understand and interpret the habits and symbols of foreign cultures.

The main character of the movie is Jack Skellington, the Pumpkin King of Halloween Town, a place inhabited by ghouls, ghosts, vampires, witches and other monsters. One day Jack stumbles upon a tree, which is a portal to Christmas Town. He enters the tree and finds himself teleported to a friendly and joyful world, completely different from his own Halloween Town. The following video track records his impressions: http://goo.gl/yCV88.

The video shows how hard it is for Jack to make any sense of the people, activities and things he discovers in Christmas Town, as they are so unrelated to his own experiences. Still, Jack wants to bring the

Christmas spirit to his own people, and he calls for a town meeting when he returns to Halloween Town http://goo.gl/zkSQt.

In the meeting, Jack presents his findings on Christmas to the Halloween Town residents. They may understand some basic facts about the holiday, but as Jack complains in the end of the scene "they don't understand that special kind of feeling in Christmasland". The problem is that the town people immediately try to interpret Christmas in their own cultural terms. For Halloween Town residents, a present in a box is a pox. A Christmas sock contains a rotten foot. Toys bite, snap and explode. Without even thinking about it, the Halloween Town people assume that their own views and experiences can be used to understand the world of Christmas. However, as any interpretivist would be happy to point out to them, this does not work. Gift giving, present wrapping and other Christmas habits are social phenomena that are created and given meanings by those who participate in them. They cannot be understood by outsiders who just observe them in a casual and disinterested manner. But understanding is what Jack seeks, as he calls out in the next video "What does it mean?": http://goo.gl/r3GcP.

Jack seeks meaning in two ways. He first tries the positivist road with observation and analysis. He puts toys into vials, inspects rag dolls, and learns Christmas rhymes by heart. In some deleted scenes, Jack also dissects a teddy bear with a scalpel, dissolves candy in test tubes, and formulates equations about Christmas notions: goo.gl/j8Xxk. However, Jack soon realizes that these kinds of investigations will not grant him any understanding of Christmas, "something's there I cannot see". So he then switches to an interpretivist mode, summarized in the phrase "Just because I cannot see it doesn't mean I can't believe it". Christmas is not understood by observing Christmas objects. Christmas is understood by believing it. Christmas is understood by making it. And the people of Halloween Town start making Christmas: http://goo.gl/7YVFe.

They become participants of the Christmas tradition by believing it, by making it, by living it. No longer are they passive observers, but instead active creators. So through their lived experiences they come to understand Christmas. Or do they? Of course they do not, and their failure to understand drives the rest of the movie forward to its tragic end. Someone may argue that this lack of understanding is a general rule and that people are so caught up in their own culture that they always interpret other cultures in terms of their own. They cannot step outside and truly understand a foreign culture, or at least their understanding is so limited and subjective that it cannot be trusted. Is this a fair conclusion? The movie offers an answer, but it would be a spoiler to give it here...

12.3 The Roles of Positivism and Interpretivism

While the differences between positivism and interpretivism may seem deep and substantive, it has been argued that many of the alleged differences are spurious, in particular the ontological ones (Weber, 2004). Furthermore, some of the positions ascribed to positivists are outdated and not supported by anyone today. Positivists would nowadays certainly agree that some parts of reality are socially constructed, including most of the research objects in the information systems area. Historically, however, some researchers have assumed that many complex social phenomena are immutable and independent of time, place and person. For example, phenomena like childhood, gender and honour have been treated as stable, well established, and independent of culture and time. Clearly, this is not the case – just compare the gender stereotypes of today's Scandinavia with those of 19th century Prussia. Researchers who have assumed that social phenomena are culturally independent have in practice ascribed their own conceptions to people in other cultures, who have actually held widely different views. As interpretivists have pointed out, this is a sure recipe for bad research.

Epistemologically, interpretivists do understand and even appreciate the positivist ambition for objectivity. However, they contend that objective research results are only attainable if the researcher restricts herself to surface level phenomena in the social world, such as correlations between income and education level. In order to obtain deeper knowledge, the researcher needs to engage closer with people to understand their views and interpretations. Obviously, this compromises objectivity, but the interpretivist sees this as a price well worth paying for the insights gained. A positivist may be less inclined to make this trade off and might argue that many results obtained through interpretivist investigations are so subjective that they are next to useless. Furthermore, the positivist may claim that typically positivist research strategies also can provide deep knowledge on social phenomena, e.g. ingeniously designed experiments such as versions of the prisoner's dilemma or the ultimatum game.

Another epistemological issue is the social construction of knowledge. Positivists would here acknowledge that any construct, framework, model or theory is socially constructed, whether its subject matter is socially constructed or not. Thus, research results are always influenced by the culture, experience and history of the researcher. This recognition is a corner stone in Kuhn's account of how researchers develop theories not only in the social but also in the physical and life sciences (Kuhn, 2012). Thus, the ephemeral and culturally dependent nature of knowledge is acknowledged by positivist and interpretivist researchers alike.

As discussed earlier, positivists tend to prefer research strategies like experiments, surveys and field studies, while interpretivists focus on case studies, action research and ethnographic studies. The pros and cons of these research strategies follow the same line of reasoning as in the previous section. Simplifying somewhat, the positivist ones provide reliable but shallow knowledge, while the interpretivist ones offer deep but unreliable knowledge. In order to overcome the weaknesses of the respective research strategies, it has been suggested to combine them. The interpretivist ones should then be used for generating and suggesting research results, while the positivist ones should be used for verifying these results.

Critical Theory and Design Science

Most social sciences have as their goal solely to explain and understand social and cultural phenomena. Critical theories, by contrast, have also added the practical and ethical goal of seeking human emancipation. As expressed by Horkheimer (1975), research should "liberate human beings from the circumstances that enslave them”. Critical theories are not only concerned with how things are but also how they might be or should be. Critical theories are critical in the sense that they question hidden assumptions and purposes in academic theories as well as in political ideologies and cultural practices. By exposing these assumptions, critical theories can make people aware of the oppressing effects of established theories, ideologies and practices. Such an awareness is the first step towards change that can set people free.

As critical theories aim to decrease domination and increase freedom in all their forms, they have been applied in many contexts, including inquires on race, gender, ethnicity and identity. In an analysis of gender within some tradition or practice, a critical theory may ask questions about the equal status of women, whether they are demeaned or idealized, and whether they are ignored or patronized. The answers to these questions can help people start to understand if and how women are subordinated in the tradition.

According to critical theory, two of the most common forms of domination in modern society are alienation and reification. Alienation is about the psychological effects of exploitation and the division of labour, where an individual is disconnected from the tools of production as well as her fellow workers. In other words, people lose control of their lives and selves by not being able to control their work. Reification is about transforming social relations into things, or more precisely social relations become mediated and expressed by things, in particular commodities and markets. For example, the patriarchal relation between a farmer and his farmhand is replaced by an impersonal relation based on money and market valuations.

Critical theories and design science share the conception that describing and explaining the world is not sufficient; it also needs to be changed. Critical theories bring about this change by raising people’s awareness of patterns of domination, thereby spurring them to action. Design science causes changes by developing and introducing new artefacts. However, critical theories and design science differ widely with respect to their goals. While critical theories aim at liberating people from oppressing structures, design science projects have the more limited purpose of satisfying stakeholder needs and wants. In other words, critical theories attempt to realize the universal values of liberty and autonomy, while design science projects are governed by the particular interests of stakeholders of a practice.

These differences in goals may even give rise to conflicts. An example could be a design science project, where a new ERP system is to be designed and introduced in a company. One group of stakeholders, the management, claims that the goal of the new system is to improve efficiency and productivity by eliminating routine work activities. However, a critical theorist could argue that the hidden motive of management is to better monitor, control and evaluate employees, which would contribute to their alienation and reduce their autonomy. The critical theorist could even claim that the design science researchers are management lackeys who help strengthen controlling and oppressive structures in the company. This example illustrates that a design science researcher needs to take a broad outlook during problem explication and requirements definition. She has to acknowledge the viewpoints of multiple stakeholders, and probe into the problem situation using different research methods, in order to get a rich and unbiased understanding.

12.4 Research Paradigms and Design Science

In design science, just as in empirical research, both the positivist and interpretivist paradigm can be applied. It is even possible, indeed common, to make use of both paradigms in the same design science project. During problem explication and requirements definition, a researcher may choose an interpretivist stance in order to obtain a deep understanding of the needs and wants of stakeholders. This understanding will help her to design and develop an artefact that is highly relevant for the stakeholders of a practice. For evaluation, however, she may value rigour more highly and decide to use positivist methods like extensive surveys and experiments in order to arrive at objectively valid results. Still, interpretivist methods may also be appropriate for evaluation, especially if there is a need to understand the subjective experiences of users. In summary, a design science project can use and benefit from positivist as well as interpretivist strategies and methods, depending on the goal and context of the project.

What design science is and is not

Design science is not design – the purposes of design and design science differ with respect to generalizability and knowledge contribution, as pointed out in Section 1.5.
Design science is not a research strategy – instead, different research strategies can be used in design science projects, as pointed out in Section 4.2.
Design science is not action research – design science always creates or positions an artefact, which is not required in action research, see Section 4.1.
Design science is not a research paradigm – a design science project can benefit from both positivist and interpretivist approaches, as discussed in Section 12.4.

So, what is design science? The definition from Section 1.4 states that design science is the scientific study and creation of artefacts as they are developed and used by people with the goal of solving practical problems. Thus, design science is a way of studying artefacts. Design science takes a problem solving stance, starting from problems experienced by people in practices and then trying to solve them. It does so by creating, positioning and repurposing artefacts that can function as solutions to the problems. In this work, design science will include empirical studies like problem explication and evaluation, but this is not the whole story. In addition, design science includes problem solving in the form of artefact design.

Further Reading

Oates (2005) discusses research paradigms in the context of information systems and computing. An introduction to interpretivism is given by Burr (2003). Vaishnavi and Kuechler (2004) discuss research paradigms and their relevance to design science. Baskerville (2008) discusses what design science is not.

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Appendix

Template for a Design Science Thesis

This appendix provides a template that can be used for structuring a design science thesis at bachelor, master or PhD level. The first parts of the template address the general background and methodology. It then moves on to the five design science activities and ends with a part on discussion and conclusions. In some sense, a design science thesis can be viewed as including five mini theses, one for each design science activity. Thus, the template includes five parts, Part IV to Part VIII, corresponding to these activities, where each part addresses its own research question. However, in many theses, some part can be omitted and/or two parts can be merged into a single chapter. For example, Part IV and part V can be merged into a chapter "Problem and Requirements"; Part VI can form a separate chapter "Development"; Part VII can be omitted; and Part VIII can form a chapter entitled "Evaluation". In this case, Part IV to Part VIII will be addressed in only three chapters. Other parts can also be merged into one chapter, and sometimes one part can give rise to several chapters.

Abstract

The abstract is to summarize the main points of the thesis. It should briefly describe the background, practical problem to be addressed, goal, choice of methods, application of methods, results, and conclusions. The abstract should be self-contained so that it can be read independently from the rest of the thesis. The abstract should be concise but yet detailed enough that a reader can decide whether the paper is of interest to her.

Part I – Introduction

Background

The background section is to provide concise information required for understanding the problem and the goal of the thesis. The background typically includes a description of the practice in which the problem arises.

Problem

The problem section is to describe the practical problem that motivates the thesis. A practical problem is often a situation that involves or causes significant difficulties, disadvantages or risks to people or organizations, such as people being exposed to health hazards, businesses losing money or citizens receiving poor service from government agencies. A practical problem can also be about new possibilities, e.g. how tablets could be used in health care. A problem should be of general interest. The problem should be described in such a way that the reader becomes convinced that it is important to address it. An example of a problem is “Many elderly experience difficulties in using high-speed scanning systems for self-service in grocery stores and refrain from using them.”

Goal

The goal section is to formulate the goal of the thesis. A goal can be formulated as a question, e.g. "How can an architecture for high-speed scanning systems for self-service in grocery stores be designed so that the systems are suitable for the elderly?" A goal can also be more directly formulated, e.g. "The goal is to design an architecture for high-speed scanning systems for self-service in grocery stores that are suitable for the elderly." The goal should relate to the problem, i.e. the problem should be addressed by achieving the goal. A goal should be of general interest, i.e. it should be interesting not only for a local practice. The section should make clear what type of artefact is to be developed, such as a model or a method.

Part II Extended Background

This part should include two sub-parts, The first sub-part should include a description of what knowledge from the knowledge base that has been used as a basis for the research carried out. The second sub–part should include a description and discussion of research that is related to the research presented in the thesis. Differences between the work of the thesis and related work should be described. Part II should give the reader basic background information for understanding the research presented in the thesis as well as a base for validating the originality of the presented research.

Part III Method

This part is to first explain why design science is an appropriate approach for the thesis. It should then provide a description of the methods used, particularly the research strategies and research methods chosen. If creative methods or systems development methods have been used, these should also be described. All choices shall be justified, and the advantages and disadvantages of the choices shall be described. The part is also to discuss alternatives and why these were not used. Relevant ethical considerations are to be made.

Part IV Explicate Problem

This part is to precisely formulate the initial problem that was introduced in Part I, explain its significance and possibly analyze its underlying causes. This part can sometimes be omitted if the initial problem is sufficiently well described and analyzed in Part I. However, there are also theses in which problem explication is a large and important part.

Research question

This section is to formulate the research question that forms the basis of the problem explication. This can be expressed as a variation of the following question: "What is the problem experienced by some stakeholders of a practice and why is it important?"

Method Application

If the problem explication was based on a literature study, this section should specify the databases and search queries that were used. If an empirical study was undertaken, the section should describe how the chosen research strategies and methods were applied. For example, if interviews were used for data generation, the design of the interview questions should be discussed as well as the set-up of the interview situation. Furthermore, the section is to show that the method application is effective, i.e. that it helps answer the research question of this part.

Results and analysis

This section is to describe and analyze the results of the problem explication. Conclusions are drawn that form the basis for answering the research question of this part. The certainty of the conclusions is to be discussed, for example in terms of validity, reliability, and transferability.

Part V: Outline Artefact and Define Requirements

This part is to outline a solution to the explicated problem in the form of an artefact and identify the requirements for this artefact.

Research question

This section shall formulate the research question that forms the basis for the requirements definition. This can be expressed as a variation on the following question: "What artefact can be a solution for the explicated problem and which requirements on this artefact are important for the stakeholders?"

Method Application

See Part IV above.

Results and analysis

See Part IV above.

Part VI Design and Develop Artefact

This section is to describe both the developed artefact and the process followed in its development. If the thesis only evaluates an artefact, this part only includes a description of it.

Development process

This section is to describe how the development of the artefact was carried out, particularly the methods used. The use of systems development methods, creative methods as well as research strategies and research methods is to be described here. Design decisions and the reasons for these (design rationale) are to be discussed.

Artefact Description

This section is to describe the developed artefact. The functionality and construction of the artefact should be described.

Part VII Demonstration

This part is to show how the developed artefact can be used in one case. The part is omitted if no demonstration was carried out.

Research question

This section shall formulate the research question that forms the basis for the demonstration. This can be expressed as a variation on the following question: "How can the developed artefact be used to address the explicated problem in one case?"

Method Application

This section is to describe how the chosen research strategies and research methods were applied. Furthermore, the section is to show that the method application is effective, i.e. that it helps answer the research question of this part.

Results and analysis

See Part IV.

Part VIII Evaluation

This part is to evaluate the developed artefact, addressing both the defined requirements and the explicated problem.

Research question

This section is to formulate the research question that forms the basis for the evaluation. This can be expressed as a variation on the following question: "How well does the artefact solve the explicated problem and fulfil the defined requirements?"

Method Application

If an empirical study was undertaken, the section should describe how the chosen research strategies and methods were applied. Furthermore, the section is to show that the method application is effective, i.e. that it helps answer the research question of this part.

Results and analysis

See Part IV.

Part IX Discussion

This section is to summarize the findings and conclusions of the preceding parts. A discussion of future research is also to be included in this part. Significance and originality is to be discussed. Ethical and societal implications of using the artefact should be discussed.

References

The reference list should be formatted according to some established reference system.

Appendices

Not mandatory. An appendix includes material that supports the thesis, but for some reason it is not appropriate to be included in the main text. An appendix may include questionnaire forms and raw data.