Chapter 1
Introduction

Empirical research describes, explains, and predicts the world. For example, the Linnaean taxonomy describes the kingdoms of animals and plants and classifies them 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.

In contrast to empirical research, design research is not content to just 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 novel artefacts in the form of 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 perspectives of other fields of human practice. As design science creates 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

Most of the activities that people carry out are structured in orderly and meaningful ways, i.e. they are not performed in isolation but are grouped together into coherent clusters, so-called practices. 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,

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drilling 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, and other tools. Another example of a practice is cooking, where people cut fruit, fry meat, boil vegetables, and so on, while using stoves, refrigerators, pans, and other kitchen utensils.

Practices can be more or less structured or formalised. Some practices take place within organisations, e.g. the production of cars in factories or the management of customer complaints in call centres. Other practices occur in informal settings, for example, kids playing ball 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 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 the practice. The desirable state is seen as better than the current one, because it allows 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.

Many practical problems are *wicked problems* in the sense that they are difficult or impossible to solve due to incomplete knowledge, contradictory and changing requirements, and the complex interplay between related problems. There is no definitive formulation of a wicked problem. For example, the problem of poverty can be expressed and reframed in many different ways, in terms of absolute or relative deprivation, access to economic or cultural wealth, or social mobility. Furthermore, there is no "stopping rule" that tells when a wicked problem has been solved; in principle, any added effort can improve on a solution to a wicked problem. Thus, a problem solver stops working on a wicked problem not because it has been solved but due to external considerations, such as a lack of time and resources.

Wicked problems can be contrasted to *tame problems*, which are problems that can be stated with all the information required for understanding and solving them and for which there exist clear criteria for determining whether they have been solved. Many engineering problems are tame problems, e.g. designing an algorithm that sorts a list of letters alphabetically or constructing a bridge of a certain length and height. In contrast, social and practical problems are often wicked, and they need to be addressed with methods that are partially different from those used to address tame problems. In particular, problem analysis and requirements definition are key concerns for handling wicked problems, as will be discussed further in Chap. 4.

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 is 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. To summarise, the term "problem" is used here to denote troublesome situations as well as promising opportunities. It can be argued that "challenge" or "practical challenge" would be better choices of word than "problem" and "practical problem", but this book sticks with the latter, well-established 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 is 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 that it be used to address a practical problem. Some artefacts are physical objects, such as hammers, cars, and hip replacements. Other artefacts take the form of drawings or blueprints, such as an architect's plan for a building. Methods and guidelines can also be artefacts, for example, a method for designing databases. Common to all these artefacts is that they support people when they encounter problems in some practice.

There are a plethora of artefacts in the IT and information systems area, ranging from algorithms, logic programmes, 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, such as keeping in touch with friends, sharing and organising photos, or playing games.

The relationships between people, practices, problems, and artefacts are summarised in Fig. 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.

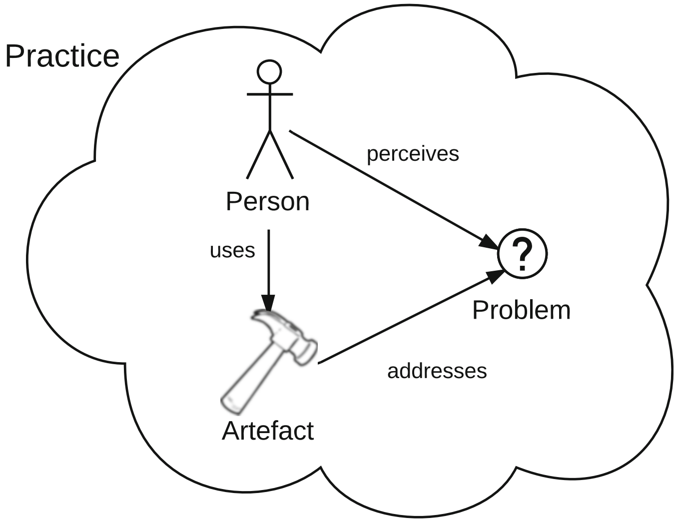

Fig. 1.1 People, practices, problems, and artefacts

1.3 The Context and 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 structure that can produce certain behaviours, and these can offer functions for people in the intended practice of the artefact. The *intended practice* is defined here as the practice that contains the practical problem that the artefact addresses.

The *functions* of an artefact are what it can do for its users, what benefits it can bring to them in their practice, what role it can play for them, and how it can support them in their activities. For example, a function of a clock is to tell the time, a function of a lawn mower is to cut grass, and a function of a truck is to transport goods. The functions of an artefact can be seen as its raison d'être—the artefact has been created to offer its functions.

In order to be able to provide its functions, an artefact must be able to perform certain *behaviours*, i.e. it must be able to carry out various actions. For example, some of the behaviours of a truck are rolling, accelerating, braking, turning, and honking. These behaviours are all essential for the main function of the truck, to transport goods. However, an artefact may also exhibit behaviours that are not relevant to any of its functions, e.g. the truck may make engine sounds and emit fumes, which are behaviours of the truck that are not needed for its transport function. While a behaviour is simply something that an artefact can do, a function is something that the artefact can do for the benefit of its users. In this sense, function is a relative concept that connects the behaviours of an artefact with the goals and activities of its users.

In order to produce its behaviours, the artefact has to be constructed and configured in a certain way. The *structure* of an artefact is about its inner workings, the components it consists of, how these are related, and how they interact with each other. Typically, an artefact is constructed from smaller parts that are assembled in such a way that they can interact with each other and produce the artefact's behaviour. An example is 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.

While the structure of an artefact is about its inside, its *environment* is about the outside, i.e. the external surroundings and conditions in which the artefact will operate. The environment of an artefact always encompasses its intended practice, including people and other objects participating in that practice. The environment may also include other practices that are affected by the use of the artefact, as well as various objects that are not related to any specific practice. As an example, the environment of a truck includes the goods transportation practice, i.e. the intended practice. 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.

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 in unintended ways. The intended effects are related to the functions of the artefact, e.g. the intended effect of using a truck is that some goods are moved from one place to another. 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 are playing 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 used directly in any specific practice. Emissions from truck driving pollute the air, which may harm many practices indirectly.

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

A common guiding principle in the design of an artefact is to hide its structure from its future users and instead to focus on its functions. Users should not need to care about the internal structure of the artefact but only about its functions, i.e. how it can serve them. Ideally, the users should not even be aware of the structure. 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 such as encapsulation, object orientation, information hiding, and service-oriented architectures.

When designing an artefact, a designer often starts by creating a specification that defines its *functional requirements*, i.e. the functions that the artefact should

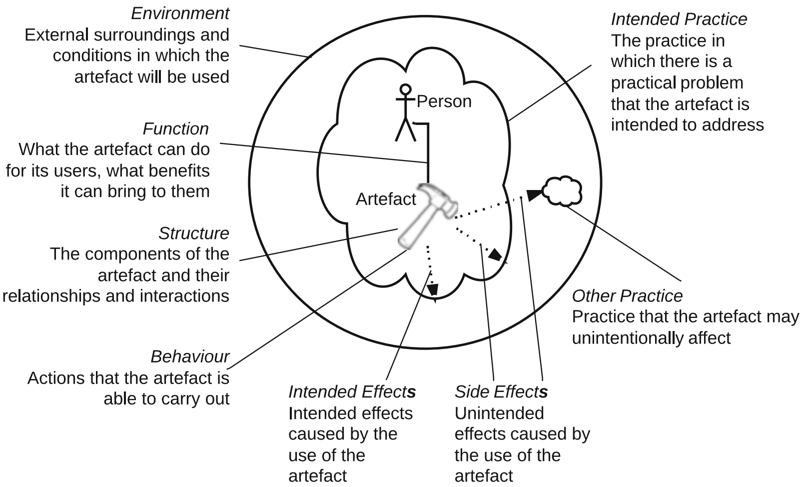

Fig. 1.2 Structure, function, and environment

offer. For example, two requirements for a watch could be 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 structure. Instead, the structure can be developed later on when the designer has a more complete understanding of the requirements. However, in practice, function and structure are almost always elaborated in an iterative way. A designer can also specify *non-functional requirements* on an artefact, i.e. requirements that do not address functionality but instead general qualities such as security, usability, maintainability, and scalability.

The distinction between structure, function, and environment is sometimes reflected in the professional roles of designers. For example, in the construction industry, a construction engineer will focus on the internal structure of buildings, including the selection of building materials, the layout of plumbing, the strength calculations, etc. An architect, on the other hand, will focus on the environment and functions of buildings in order to cater for external constraints as well as for 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 the 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 enterprise resource planning (ERP) systems in companies affects their internal communication.

Artefacts are also studied in design science, where they are investigated as solutions to practical problems that people experience in practices. In design science, researchers take an intentional stance in the sense that they view an artefact as something that should support people in a practice. The researchers are not disinterested observers but take on the role of designers that create useful objects:

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. Design science researchers do not only think and theorise about the existing world. They model, make, and build in order to create new worlds. They produce both a novel artefact and knowledge about it and its effects on the environment. In particular, they need to formulate problem statements, determine stakeholder goals and requirements, and evaluate proposed artefacts. In other words, artefacts as well as knowledge about them are research outcomes for design science.

In design science, an artefact is an object made by humans with the intention that it be used to address a practical problem. In other words, some stakeholders have formulated a goal of the artefact, which is related to some 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.

In this book, design science is viewed mainly from an IT and information systems perspective. However, the principles underlying design science are applicable to many other areas, e.g. medical science, as discussed below.

1.5 Design and Design Science

Design science may appear to be very similar to design, as both focus on the development of artefacts. Both of them also aim at novelty, i.e. they are intended to produce or investigate original artefacts that differ from existing ones. However, their purposes are different with respect to their generalisability and their contribution to knowledge. While design is a process for developing a working solution to a problem that may only be relevant to a single actor, design science is intended to produce and communicate 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, group, or organisation engages. In contrast, design science produces results that are relevant for a *global practice*, i.e. a community of local practices, and for the research community.

The different purposes of design and design science give rise to three additional requirements on design science research. 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 needs to fulfil three conditions.

First, the project has to choose an overall research strategy for investigating the problem situation and for eliciting stakeholder requirements. This strategy includes research methods for data collection, e.g. questionnaires for large groups of health-care professionals and in-depth interviews with selected physicians and health-care managers. Moreover, the strategy includes methods for analysing the generated data. The project also needs to evaluate the artefact produced using adequate research strategies and methods.

Secondly, the project has to relate the produced results to existing knowledge within various subareas of health informatics and information systems. This knowledge includes 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.

Thirdly, the project has to disseminate its results to both researchers and health-care professionals through publications in journals and conferences as well as through presentations at health-care fairs, professional conferences, and other similar events.

The relationships between a design science project and local and global practices are depicted in Fig. 1.3. The figure indicates that a design science project may, but does not have to, utilise empirical data from a local practice, and its results may provide a contribution to that practice. However, the project should always build on

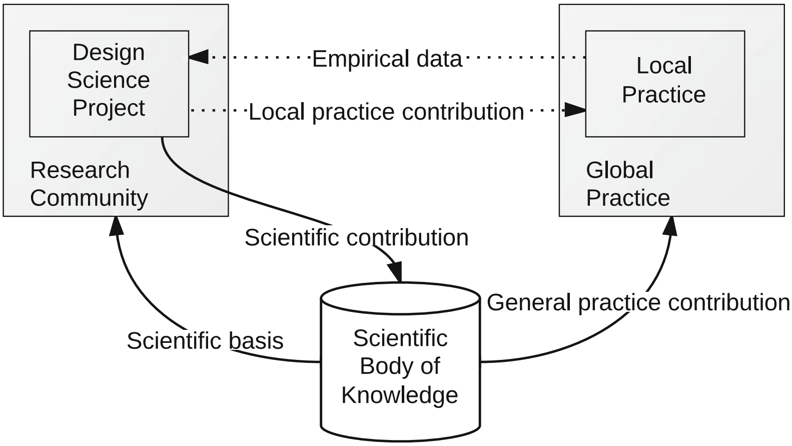

Fig. 1.3 Local and global practices in design science research [adapted from Goldkuhl (2012)]

some scientific body of knowledge and contribute to it. This body of knowledge should also be of relevance not only to a research community but also to a global practice.

While a design science project always should contribute to a global practice as well as to a scientific body of knowledge, the project can still be carried out within a local practice. Iivari (2014) investigates two different strategies of doing design science research. In the first strategy, a researcher constructs or builds a generic artefact as a solution to address a problem in a global practice. In the second strategy, a researcher attempts to solve a specific problem in a local practice by building a concrete artefact in that specific context and, from that experience, distils prescriptive knowledge that can inform a general solution. Thus, the researcher remains situated within the local practice for almost the entire duration of the project, and generalisation to a global practice does not occur until the end of the project.

1.6 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" (Encyclopaedia Britannica, *Medicine* 2014). 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 such as animism, shamanism, and divination. Today, these relationships have largely been broken, and instead, medical practices are usually supported by medical science.

Medical science is, in many ways, akin to design science. There is a practice, the medical practice, that aims to heal 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 to medical science.

1.7 Kinds of Design Science Contributions

A design science contribution can take several different forms. It can be based on a new artefact that is radical in the sense that it opens up entirely new avenues of human endeavour. However, a new artefact can also be an improvement upon an established solution to a well-known problem or just a marginal modification of an existing artefact. Another kind of design science contribution is the use of an existing artefact for a new purpose.

In order to classify the various kinds of design science contributions, Gregor and Hevner (2013) suggest that they can be positioned along two dimensions: application domain maturity and solution maturity. Application domain maturity is about the maturity of the practice for which the contribution is intended. Solution maturity is about the maturity of artefacts that could be used as a starting point for finding solutions. Based on these dimensions, Fig. 1.4 depicts a matrix that identifies four kinds of design science contributions:

Invention—New Solutions for New Problems This kind of contribution is a radical innovation that addresses an unexplored problem context and offers a novel and

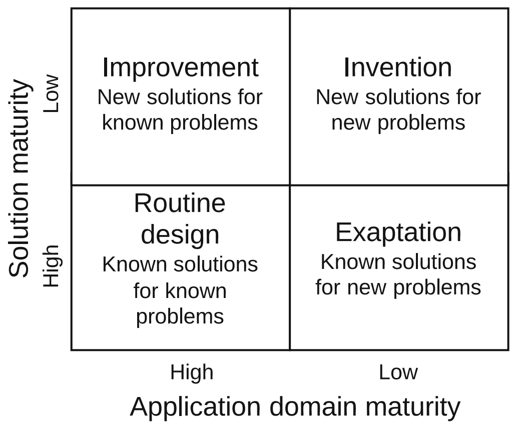

Fig. 1.4 Kinds of design science contributions [adapted from Gregor and Hevner (2013)]

unexpected solution. Such a contribution can enable new practices and create the basis for new research fields. Some examples of inventions are the first X-ray machine, the first car, and the first data mining system. Inventions are rare and typically require broad knowledge and hard work as well as ingenuity and a bit of luck in order to occur.

Improvement—New Solutions for Known Problems This kind of contribution addresses a known problem and offers a new solution or a substantial enhancement to an existing one. Improvements may concern efficiency, usability, safety, maintainability, or other qualities; see Sect. 6.5. Some examples of improvements are the first sport bike, an X-ray machine with substantially reduced radiation, and a data mining system able to handle very large data sets. Improvements are probably the most common kind of design science contribution, and they can be challenging because a researcher needs to show that a proposed solution actually improves on the state of the art.

Exaptation—Known Solutions Extended to New Problems This kind of contribution adapts an existing solution to a problem for which it was not originally intended. In other words, an existing artefact is repurposed, or exapted, to a new problem context. 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. Exaptations occur frequently in design science research.

Routine Design—Known Solutions for Known Problems This kind of contribution is an incremental innovation that addresses a well-known problem by making minor modifications to an existing solution. Much of practical professional design would fit into this category, e.g. the design of a new smartphone with slightly better specifications than its predecessor. Routine designs typically do not count as design science contributions because they do not produce new knowledge of general interest, but they can still be valuable design contributions.

One way of understanding the nature of exaptations is to note that a designer usually not only produces an artefact in isolation but also a use plan for it. The *use plan* tells when and how people should use the artefact. For example, a use plan for aspirin, when used as a pain killer, could state that the medicine should be taken in a medium dose when the pain occurs. However, when used as a preventive measure against blood clotting, the medicine should be taken in small doses three times a day. In these two cases, the artefact (aspirin) is the same, but the use plans differ. Thus, exaptation is also design, but it is design of a new use plan, not a new artefact.

1.8 Technical Artefacts and Socio-Technical Systems

Some artefacts are purely material and have simple relationships with their environments, e.g. a knife or a hammer. Other artefacts are deeply embedded in a complex environment that contains not only other artefacts but also humans and their social relationships, e.g. a reception desk at an airport. The desk is not there just to serve a few people in isolation but instead is a part of a huge, interrelated system: the civil aviation system. This system includes buildings, aircraft, runways, luggage trolleys, and many other physical objects. It also includes humans, such as pilots, stewards, and passengers as well as the laws, rules, and norms that govern their behaviour. In this sense, the civil aviation system is a *hybrid system* consisting of physical, biological, and social objects.

A *socio-technical system* is a hybrid system that includes technical artefacts as well as humans and the laws, rules, and norms that govern their actions. In contrast, a *technical artefact* is a material artefact. Socio-technical systems are also artefacts in that they have been purposely designed to address a practical problem or enable some human endeavour. However, they are, at the same time, emergent phenomena that evolve due to spontaneous and unforeseen interactions among the humans in the systems.

The design of socio-technical systems includes a number of challenges due to their distinctive characteristics, in particular the roles and perspectives of people in such systems, the vagueness of systems boundaries, the need for rules and coordination mechanisms, and the low degree of systems controllability.

Many people participate in a socio-technical system, and they play different roles. There are users who benefit from the services provided by the system and operators who as professionals manipulate and manage the system, thereby ensuring its proper functioning. For example, in an aviation system, the users are the passengers who are transported, while the operators belong to several professional groups, including pilots, luggage personnel, and security guards. Due to their different roles, the participants in a socio-technical system have different interests and perspectives, and this contributes to the complexity of the system. A recent trend in socio-technical systems is to eliminate the operators or at least to substantially reduce their numbers. For example, autopilots and computerised air traffic control systems reduce the need for pilots and air traffic controllers. However, there will always be users in socio-technical systems, as they constitute the raison d'être for the systems.

The behaviour of technical artefacts is determined by the laws of physics and other natural sciences. However, the behaviour of socio-technical systems also depends on the actions and interactions of people. Thus, in order to manage and govern a socio-technical system, there is a need for social mechanisms that can coordinate the actions of its participants. Typically, these mechanisms take the form of laws, rules, norms, and traditions that inform people how to behave, often associated with sanctions for deterring inappropriate conduct. However, there is always a risk that people will choose not to follow the rules. In fact, designing rules that people do accept and follow is one of the most challenging tasks in building socio-technical systems. As stated by Bennis (1999), managing people is like herding cats.

Another challenge in designing socio-technical systems is to decide on the boundary of the system. In practice, every socio-technical system is embedded within another larger socio-technical system. For example, the baggage check-in system at an airport is embedded in the airport system, which, in turn, is embedded in the civil aviation system. There are no natural boundaries, where one system ends and another begins; instead, designers have to choose where to draw the boundaries. If the boundaries are drawn too narrowly, important aspects may be missed, resulting in a malfunctioning system. However, if the boundaries are drawn too widely, the design task may become overwhelming.

In summary, the behaviour of socio-technical systems cannot easily be predicted or controlled. Different people in different roles with different backgrounds and perspectives give rise to conflicts and complexity. Social rules for controlling the behaviour of people can easily be disregarded or outright violated. Vague and changing system boundaries cause uncertainty and unclear responsibility. As a consequence, socio-technical systems are more difficult to manage and control than technical artefacts. This also means that problems occurring in socio-technical systems often are wicked, with vague formulations that only allow for partial and provisional solutions.

When carrying out design science research on socio-technical systems, or on technical artefacts to be used in such systems, social and organisational issues come to the fore. Analysing problems in social contexts, eliciting requirements from various stakeholders, and evaluating solutions in organisational settings become key activities for the researcher. For this purpose, research strategies and methods from the social sciences can be used to produce both practical and reliable results. Chap. 3, therefore, provides a brief overview of the most important research strategies and methods in the social sciences.

1.9 Summary of Chapter

- *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.
- An *artefact* is an object made by humans with the intention to be used for addressing a practical problem.
- An artefact can be described by specifying:
  - The *function* of the artefact, that is, what the artefact can do for its users.
  - The *structure* of the artefact, that is, the inner workings of the artefact, the components it consists of, and how these are related.

  - The *environment* of the artefact, that is, the external surroundings and conditions in which the artefact will operate.
  - The *effects* of the artefact, that is, how the use of the artefact will change its environment. Effects can be divided into *intended effects* and *side effects*.

- An artefact is developed to address a practical problem. A *practical problem* is a gap between the current state and a desirable state, as perceived by the participants in a practice.
- A *practice* is a set of human activities performed regularly and seen as meaningfully related to each other by the people participating in them.
- Design science can be contrasted to *empirical science*, such as natural and social sciences. In empirical science, researchers describe, explain, and predict. In design science, researchers also design and develop artefacts for improving practices, thereby changing the world.
- The outcome of design science research is not only artefacts but also contextual knowledge about the artefacts.

1.10 Review Questions

1. Can Internet surveillance be viewed as a practice? If so, give some examples of practical problems that appear in this practice.
2. A common practical problem when introducing new information systems or services is that many people prefer not to use them. Explain this problem in terms of a gap between two states.
3. Which of the following objects are artefacts—a stone, a stone axe, a coin, a tiger, a German shepherd, the planet Jupiter, the climate, or a company?
4. Can two artefacts with different structures exhibit the same functions? If so, give an example.
5. Describe a tablet in terms of structure, behaviour, function, and effects.
6. Are the side effects of using an artefact always harmful for its environment?
7. A photo sharing service is an artefact. Give an example of a design science study and a social science study that can be carried out on this artefact.
8. In what ways can a design science project be more complex than a design project?
9. In what ways can a design project be more complex than a design science project?
10. Why is a function of an artefact a relative concept? Give some examples of other relative concepts presented in Chap. 1.
11. It is important to relate an artefact to a practice. Why?
12. Give an example of a wicked problem in a social-technical system and how a design science project can address this problem.

1.11 Answers to Selected Review Questions

2. The current state is that people do not want to use the new system, and the desirable state is that people do want to use the system.
3. A stone, a tiger, and the planet Jupiter are not man-made objects, so they are not artefacts. A stone axe and a coin are artefacts, as they are man-made with the intention of solving practical problems relating to chopping and exchange, respectively. A German shepherd is a borderline case, as this race of dog has been bred by people for solving the practical problem of herding sheep. A more extreme example is the Harvard oncomouse that has been genetically modified to make it suitable for cancer research. A company is also a borderline case, as it is partially an emergent phenomenon created through interactions among people, but also a socially designed and constituted entity. Possibly, the climate can also be seen as a borderline case, in particular, if it is substantially modified in the future by humans for their purposes. Thus, there is not a sharp dividing line between artefacts and natural objects.
4. An electric car and a hybrid car have different structures, but they offer the same function of transporting people and goods. However, they have different behaviours, as only the hybrid car produces emissions.
6. No. An example is that using lamps in a cold room can help to make the room warmer.
7. A design science study could be to design and evaluate a novel mechanism for informing people about new photos that have been added. A social science study could be to investigate in what ways people experience stress when using the photo sharing service.
8. A design science project requires a rigorous application of research methods and a critical analysis of its results that relate them to a scientific body of knowledge. Still, a design project may also need to follow professionally recognised methods, and its results should typically be compared to the state of the art.
9. A design project requires that its results fulfil the demands and expectations of the customers, and it is typically carried out under strict time and budget constraints. Furthermore, a design project in an organisation needs to handle political issues. Still, a design science project may experience similar constraints and issues with regard to funding agencies and institutional politics.

1.12 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). A starting point for Simon is that the world that people inhabit today is primarily human-made. He investigates the role of design in this context and asks how science can inform design.

An early paper on design science was written by March and Smith (1995), which presents a two-dimensional framework for research in information technology. The first dimension is based on common types of research activities in design and natural science: build, evaluate, theorise, and justify; these will be further discussed in Chaps. 4–9. The second dimension is based on the kinds of artefacts produced by design science research: representational constructs, models, methods, and instantiations; these will be introduced in more detail in Chap. 2. Another highly influential paper was written by Hevner et al. (2004), which contrasts two research paradigms in the information systems area: behavioural science and design science. The paper proposes a conceptual framework and guidelines for understanding, executing, and evaluating design science research. It also argues that within design science, knowledge and understanding of a problem and potential solutions are achieved through building and applying artefacts. Österle et al. (2010) discuss the importance and relevance of design science. They argue that design science research is key to the achievement of results that are both rigorous in an academic sense and relevant for information systems practice. Wieringa (2009) investigates the difference between, as well as the mutual nesting of, knowledge questions and practical problems in design science and argues that these need to be addressed using different methods. Design science has received much attention not only within information systems but also in management science. Pandza and Thorpe (2010) argue that the design analogy is relevant to achieving an understanding of the different forms of management studies, but that it is fairly narrowly applicable.

Hevner and Chatterjee (2010) offer a thorough reference text on design science research that includes chapters by several authors. The chapters address the key principles of design science research, design for software-intensive systems, people and design, the past and present of software designs, evaluation methods, and design creativity. Vaishnavi and Kuechler (2004) have designed a website for design science. It includes an overview of design science research, discusses design science research methodologies, investigates the philosophical grounding of design science research, and offers a comprehensive bibliography of design science publications as well as other resources. New contributions to design science are regularly published, e.g. in the conference series Design Science Research in Information Systems and Technologies (DESRIST) and the SIG Prag workshop series on IT Artefact Design & Workpractice Improvement (ADWI).

Rittel and Webber (1973) investigate the notion of the wicked problem in the context of social policy. They provide a number of characteristics of wicked problems and conclude that they cannot be addressed using scientific methods, as science focuses on tame problems. In contrast, Farrell and Hooker (2013) argue that science also addresses wicked problems and that there is a common, core, cognitive process to both design and science.

The text in Sect. 1.3 on the context and anatomy of artefacts builds on the framework proposed by Gero (1990) and Gero and Kannengiesser (2004). Similarly to the work by Gregor and Hevner (2013), Gero (1990) uses this framework to distinguish between routine design, innovative design, and creative design.

The notion of the artefact has been extensively investigated in various disciplines, including philosophy and psychology. Franssen et al. (2013) have edited a book on artefact ontology that addresses two key topics of metaphysics: the identity of entities and the foundations of classification. It discusses these topics not for natural entities but for human-made ones, i.e. artefacts. Vermaas et al. (2011) argue that artefacts always are associated with a use plan, as discussed in Sect. 1.7. A related notion is that of a treatment, introduced by Wieringa (2014), that can be seen as an aggregation of an artefact and a use plan.

Gill and Hevner (2013) investigate the notion of usefulness in design science. The common view is that usefulness of an artefact is primarily about its immediate relevance in a practice, i.e. how well the artefact addresses the problem for which it has been designed. However, usefulness can also be viewed in a more dynamic way. This means that the usefulness of an artefact depends also on its ability to provide a basis for further evolution, i.e. an artefact that can be further refined and improved is more useful than one that has no room for improvements. Based on these distinctions, Gill and Hevner (2013) propose a fitness-utility model that captures the evolutionary nature of design improvements. Their work also has a bearing on the difference between design and design science, where design often focuses on immediate relevance, whereas design science emphasises the evolution of a knowledge base.

The notion of practice has been hugely influential in modern social science through works such as those by Bourdieu and Nice (1977) and Giddens (1986). Cetina et al. (2005) have edited a text on the role of practice and practices in human activity. Practice research and its relationships to design science are investigated by Goldkuhl (2012). Several key concepts of practice research are introduced, including local practice contribution vs. general practice contribution, theorising vs. situational inquiry, and abstract vs. situational knowledge.

Adler and Pouliot (2011) discuss the notion of practice and differentiate between behaviour, action, and practice, where actions are behaviour with meaning and practice are actions repeated over time and space embedded in a particular context. Actions in a practice are socially developed through learning and training. Adler and Pouliot (2011) present five characteristics of a practice: (1) practice is performance, i.e. the process of doing something; (2) practice tends to be patterned, i.e. actions are repeated over time and space; (3) practice is more or less competent in the meaning that it can be done correctly or incorrectly (in a social recognisable way); (4) practice rests on background knowledge; and (5) practice weaves together the discursive and the material world, i.e. without written and spoken communication, people cannot make a difference between behaviour and practice, and the practice is mediated by material artefacts.

Bider et al. (2013) propose a model that can be used for identifying and conceptualising different strategies for carrying out design science projects. The model suggests that design science research can be viewed as movements in a space of specific situations, problems, and solutions, i.e. in a local practice, and generic situations, problems, and solutions, i.e. in a global practice.

Sometimes, the relationship between research and practice is viewed as a linear transfer of knowledge and technology from research laboratories to practice settings. Wieringa (2010) shows that this view is an oversimplification, noting that, historically, a great deal of technological development has occurred without research being involved and that research has often investigated past innovations rather than prepared for new ones. Wieringa (2010) argues that these observations require an extended framework for design science that makes a distinction between practical problems and research questions. In a later book, Wieringa (2014) describes such a framework in detail.

Section 1.8 builds on the work by Vermaas et al. (2011), who offer a philosophical analysis and characterisation of the relationship between technical artefacts and socio-technical systems, including their ethical status and the possibilities for designers to influence this status.

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