2 Knowledge Integration by SMEs – Framework

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2.1 Introduction

As indicated in Chap. 1, for high-tech SMEs, integrating and managing *external* knowledge is a vital aspect of knowledge management (KM). Moreover, it is not only necessary to *manage* knowledge, but there are several operational activities that are also relevant and challenging. To denote this difference with 'normal' KM, we use the term 'Knowledge Integration' (KI) instead of KM throughout this book. This chapter explains this concept of KI, which is summarized in Fig. 2.1. The chapter helps to understand the main concepts and dynamics of KI in high-tech SMEs. As shown in Fig. 2.1, we concentrate on KI in new product development (NPD). As we explain below, this is because this is one of the core processes of high-tech SMEs. While the focus of this whole book is on the middle part of Fig. 2.1, this chapter also explains the left and right parts for a better understanding of the context in which this middle part is taking place.

This chapter is organized as follows: Sect. 2.2 touches upon the specific characteristics of high-tech SMEs. Consequently, Sect. 2.3 discusses the types of knowledge that are used for NPD and the various sources from which this knowledge can be obtained. Sect. 2.4 elaborates on the KI activities that are executed to identify, acquire, and utilize this knowledge for the NPD process. Sect. 2.5 provides a discussion on problems that can occur during KI and types of solutions that exist. Finally, the chapter concludes with a summary and conclusions in Sect. 2.6.

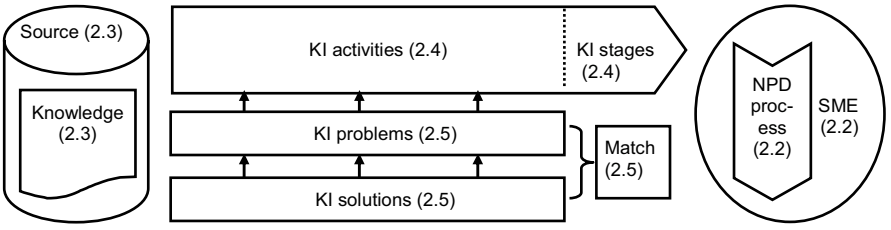

Fig. 2.1. KI model and overview of Chap. 2

2.2 High-tech SMEs: Characteristics and Differences

Although SMEs differ from large size enterprises (LSEs) by their size, it is not size *per se* that makes them different. The main effect of their smaller size is that SMEs have less economies of scale and fewer resources than LSEs. This gives them behavioural advantages (for example, rapid decision-making, flexibility, less strict regulations, governmental support, fast internal communication) rather than material advantages (for example, possessing research facilities, access to external capital, professional management, risk spreading) [22, 23]. These characteristics cause SMEs and LSEs to play different roles in society [14]:

- Generation of new basic technology: LSEs (and universities)
- Daring implementation in new product/market combinations: SMEs
- Large scale, efficient production and distributions: LSEs
- Adaptations for specialized or residual market niches: SMEs

High-tech SMEs distinguish themselves from other SMEs in that they (a) employ more scientific and technically qualified people; (b) face considerably higher rates of product obsolescence; (c) invest larger sums in R&D; (d) focus on developing new products from new technology; and (e) rely more on rapid, efficient new product introductions [2, 7]. Therefore, one of their core processes is new *product* development (NPD), which can account for up to 85 % of the total cost of the product [19]. *Process* development is more likely to take place in LSEs, since it focuses on streamlining processes and cutting down production costs [6].

To understand NPD, it is useful to have a look at a few models of the NPD process. The innovation adoption model of Rogers [21], which consists of six phases, is well known: (1) Identification of needs/problems; (2) research (basic and applied); (3) development; (4) commercialization; (5) diffusion and adoption; and (6) consequences. Since external knowledge for product development is mainly relevant in the first three stages, the latter stages are less relevant for this book. A model that focuses on the earlier stages of product development is Pahl & Beitz's [18] engineering design model that discerns four stages: (1) planning and clarifying the task; (2) conceptual design; (3) embodiment design; and (4) detail design. Cooper's [3] model is also well known. It provides decision gates after each of the five phases of (1) preliminary analysis; (2) business case; (3) development; (4) pilot study; and (5) launch and implementation.

Although these models are very helpful for understanding NPD, they offer little insight into the type of knowledge that is needed. A three-stage model that is used by several others offers these insights [27, 10, 24, 1]. This model discerns a creative stage, a selection stage, and a design stage. These are defined as follows:

- *Creative stage or generation of options:* in this stage, knowledge is collected to find product ideas, requirements, etc. This is a diverging stage in which broad and little specified knowledge plays an important role.
- *Selection of options*: alternative options are specified, priorities and evaluation criteria are set and those options are selected that are most promising. This is a converging stage in which more specified and directed knowledge is needed.

- *Design:* when an option is chosen, design can go into more detail. This is a deepening stage in which detailed and very specific knowledge is crucial.

The ordering of these stages should not imply that NPD is a linear process. In practice, the stages occur simultaneously and in various orders.

Although we have distinguished high-tech SMEs from other organizations, we have to realize that SMEs are very diverse as well. The scope of this diversity becomes clear when we look at the official International Standard Industrial Classification (ISIC) of high-tech and low-tech industries (see Table 2.1).

Table 2.1. Industry classification (source: OECD [16])

High-technology industries	**Medium-low-technology industries**
Aircraft and spacecraft	Coke, refined petroleum and nuclear fuel
Pharmaceuticals	Rubber and plastic products
Office, accounting, computing machinery	Other non-metallic mineral products
Radio, television, and communications equipment	Fabricated metal products, except machinery and equipment
Medical, precision and optical instruments	Basic metals
	Building and repairing of ships and boats
Medium-high-technology industries	**Low-technology industries**
Electrical machinery and apparatus	Other manufacturing and recycling
Motor vehicles, trailers and semi-trailers	Wood, pulp, paper, paper products, printing and publishing
Chemicals excluding pharmaceuticals	Food products, beverages and tobacco
Railroad and transport equipment, Machinery and equipment	Textiles, leather and footwear

Differences between individual SMEs will be large, for example, in terms of company size, age, and country. However, we are convinced that KI is relevant for all SMEs in the high-tech and medium-high-tech industries of Table 2.1. In Chap. 3 we will see to what degree KI is different – or similar – for these various companies.

2.3 Types and Sources of Knowledge

The defining of knowledge is not trivial because, in the literature, there are as many definitions and typologies of knowledge as there are authors that write about it. It is also not value-free because every definition and typology is made for some reason, that is, it allows you to treat various types of knowledge differently.

In Chap. 1, three types of knowledge were defined: tacit, explicit, and latent knowledge. This typology is useful because these three types of knowledge require very different KI processes, involve different problems, and ask for different solutions – as can be read throughout this book.

In addition to the general definitions and typologies of knowledge that were mentioned in Chap. 1, numerous definitions and typologies of knowledge exist in the NPD domain. We distinguish three main categories that are needed for NPD [17]: customer/market knowledge (requirements; what should the product do?), technological knowledge (design; what should the product features be?), and organizational knowledge (process: how should the product be realized?). These are explained and exemplified in Table 2.2.

Table 2.2. Typology of knowledge needed for NPD [based on 4]

Type of NPD knowledge	Example
Customer / market knowledge	
Design criteria and specifications	Understanding of user requirements, specifications
New product ideas	New product/market combinations
Knowledge about the market	Trends, needs and demands of market segments
Socio-economic knowledge	Economic climate, cultural factors
Governmental knowledge	Legislation, political situations, policy changes
Technological knowledge	
Scientific and engineering theory	'Laws' of nature, theoretical tools
Technical process knowledge	Required steps in specific chemical processes
Properties of materials	Properties of natural and artificial materials
Design concepts	Operating principles, normal configurations
Design instrumentalities	Judgment skills, ways of doing and thinking
Design competence	General and product-specific design competence
Practical experience	Best practices
Experimental and test procedures	Product testing procedures, computer simulation
Research instrumentalities	Ability to use experimental techniques and equipment
Research competence	General and specialized research competence
Experimental and test data	Results of test procedures
Operating performance	Performance of components or materials in pilots
Organizational knowledge	
Knowledge of manufacturing	Ability to manufacture, capacity, logistics
Production competence	Competence in pilot production/scale-up
Knowledge of support processes	Management information, principles of organization
Knowledge of knowledge	Location and availability of particular knowledge

As Table 2.2 shows, there is a lot of variety in the knowledge that is needed for NPD. For example, on the one hand, NPD requires long-term capabilities, such as design and research competences, while on the other hand; it also requires knowledge that might just be collected instantaneously, like new product ideas or properties of a specific material.

When we look at Table 2.2, it may seem that knowledge used in NPD is mainly explicit. However, the contrary is the case [15, 25]. It is even said that one core problem in NPD is the over-reliance on explicit rather than tacit knowledge [19]. We therefore stress that the knowledge inside the different categories of Table 2.2 can be tacit, latent, or explicit and is even more likely to be tacit or latent than explicit.

The various types of knowledge come from a diverse set of sources, ranging from formal expert systems to informal chats with colleagues. These sources are often characterized by dichotomies, that is, by giving two extremes of a dimension. The most important of these dichotomies are listed below.

A first dichotomy is the distinction between *internal* and *external* sources of knowledge. Internal sources are sources within a company's boundaries. Examples are colleagues, personal archives, and intranets. External sources are sources outside a company's boundaries. Mostly these sources belong to other organizations or individuals. Examples are the Internet, public libraries, and customers.

A second dichotomy is the one between *personal* and *impersonal* sources. Personal sources refer to direct human contact and include family, friends, and close business associates. Impersonal sources are typically written and include trade publications, newspapers, and management information systems. This distinction resembles the distinction between oral and written sources of knowledge.

A related but different dichotomy is the distinction between *formal* and *informal* sources of knowledge. Knowledge from formal sources is usually structured according to strict rules. Collecting knowledge from formal sources requires much expertise and is usually costly [13]. Examples of formal sources are conferences, journals, research centres, and universities. Examples of informal sources are conversations, colleagues, and other companies [9].

A final dichotomy is the distinction between *nearby* and *remote* sources. A core difference between the two types is that nearby sources can easily be visited and remote sources cannot. All conditions equal, knowledge transfer is harder from remote sources than from nearby sources. In some cases, knowledge can only be collected by someone being physically present at the source, because it is embedded in the structure and processes of a company, or in the machines that are used [e.g. 26].

With respect to the sources of knowledge that SMEs use for NPD, it has repeatedly been shown that they use mainly knowledge of their close partners, such as customers and suppliers, and that they prefer personal above impersonal sources, informal above formal sources, and internal above external sources [20, 8, 9, 11].

To illustrate the diversity of sources of knowledge that SMEs use for their NPD, Table 2.3 shows a top-10 of sources ranked on their relative importance [9].

Table 2.3. Sources of NPD knowledge [from 9]

Rank	Source
1	Customer
2	Specialized magazines
3	Production employees
4	Staff
5	Suppliers
6	Sellers
7	Brochures and catalogues
8	Industrial fairs
9	Commercial fairs
10	Business magazines

We find it remarkable that some sources fall outside of this top-10 and thus are less important than we might expect. For example, consultants appear at place 18, the board of directors at place 24, and universities even at place 26 in this ranking. Although these sources' main role is to provide the SMEs with knowledge or information, it seems that they do not fulfil this role towards SMEs.

2.4 KI Processes and Activities

There are several processes for managing the various types of knowledge from the various sources described in Sect. 2.3. To understand these processes, it is useful to see their relation with the NPD process. This relation is depicted in Fig. 2.2, which zooms in on the relation between the KI activities, KI stages and the NPD process as they were depicted in Fig. 2.1.

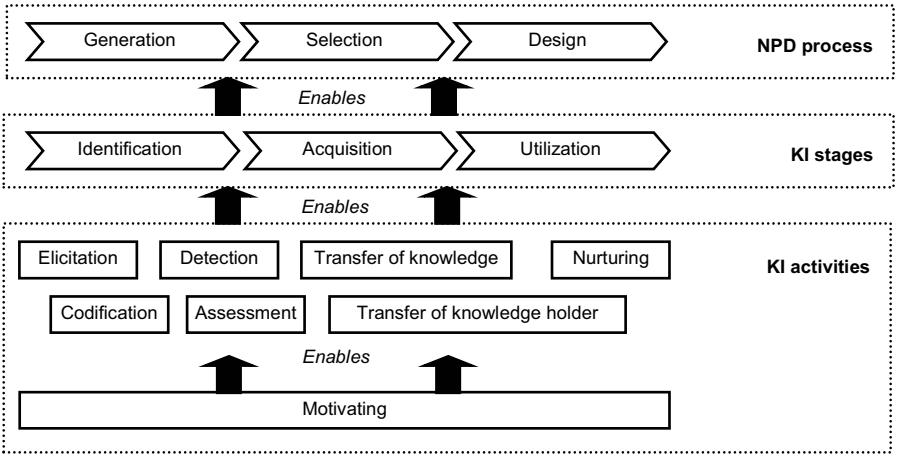

Fig. 2.2. The relation between NPD, KI, and knowledge activities

Fig. 2.2 explains that the NPD process is supported by KI activities in three KI stages that are performed when there is sufficient motivation. We have defined NPD as the generation, selection, and design of new product(idea)s (see Sect. 2.2). In order to execute the three NPD phases, developers need knowledge both from within their firm and from outside their firm in each NPD phase.

The middle part of Fig. 2.2 demonstrates that this knowledge needs to be identified, acquired, and utilized in the NPD process. We have called the internal processes that are the focus of most of the KM literature *utilization*. Because external knowledge needs to be acquired before it can be utilized, a stage of *acquisition* (not necessarily commercial acquisition), that precedes the utilization stage, is included in the model. Correspondingly, to acquire external knowledge it needs to be identified first. Acquisition is therefore preceded in the model by a stage of *identification.*A KI process can start in two different ways. *Need-driven* KI starts

with a need for certain knowledge. Consequently, companies will actively seek to fulfil their need for knowledge. On the contrary, *opportunity-driven* KI does not start from a knowledge need (or gap), but from knowledge that is found accidentally or by scanning the environment.

The lower part of Fig. 2.2 illustrates that the identification, acquisition, and utilization of knowledge can be realized by eight KI activities, of which motivation supports the other seven activities. While Fig. 2.2 was already zooming in on the middle part of Fig. 2.1, we now further zoom in on the KI activities mentioned in Fig 2.2. These activities are explained below in what we have called the 'KI Watermill model' (see Fig. 2.3). Each of the activities is explained in more detail in Chaps. 4-10 of this book.

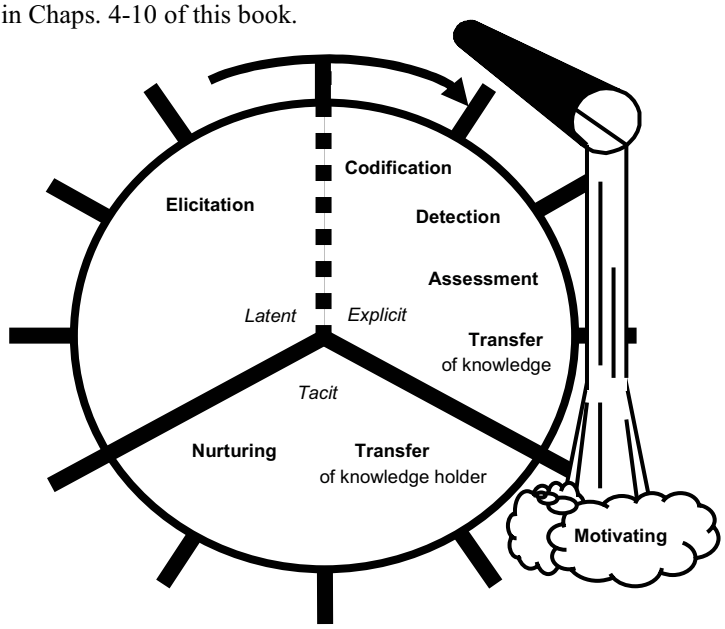

Fig. 2.3. The KI watermill model

We define KI activities as those transactions or manipulations of knowledge where the knowledge is the object, not the result. For instance: finding, studying, and institutionalizing a new production process are all KI activities, but producing accordingly is not.

This division into eight activities is a high-level division. Every activity aggregates a set of sub-activities that uniquely fit other distinct conditions. This is further described in Chap. 4. As depicted in Fig. 2.3, the rationale behind the following categorization is that each knowledge type tolerates a different sort of activity and that people need to be motivated to execute any of them.

Activities for Latent Knowledge

By definition, as long as the knowledge is latent, it can be used by its holder exclusively (others can imitate him, but only blindly). Thus the only pertinent activity is to make it explicit by elicitation. For latent knowledge that remains latent, the KI activities are similar to those for tacit knowledge (see below). Elicitation is depicted by the dotted line in Fig. 2.3 and is defined as:

- Elicitation*:* Explication of unarticulated *latent* knowledge or engendering new insight(s). If successfully performed, the knowledge in point becomes *explicit*.

Activities for Explicit Knowledge

Explicit knowledge is the type of knowledge that is easiest to manipulate by the "classic" knowledge activities. To make it clear: only explicit knowledge can be acted upon directly. As for tacit or latent knowledge, only their outcomes are discernible. For example: when a firm detects a skilful designer, it is his or her marvellous design that is explicitly detected, not the skill itself. The following activities are defined for explicit knowledge:

- *Codification:* articulation and transit of explicit knowledge from a human source to any kind of media, either straightforward (e.g. plain text or model) or adapted (e.g. embedded in a work procedure). Once codified, the knowledge is detached from its source and independently transferable to others.
- *Detection:* intended or accidental identification of useful explicit knowledge.
- *Assessment:* Attaching credibility, value, significance or meaning to explicit knowledge, either actively or by omission (e.g. ignorance, unawareness).
- *Transfer of knowledge:* addressed transit of *explicit* knowledge from a human source directly to other human(s).

Activities for Tacit Knowledge

Assuming that tacit knowledge is inexplicable whatsoever, the tacit realm is tightly delimited, allowing just two options.

- *Transfer of knowledge holder:* making tacit knowledge available by repositioning its source (human or an artifact that embodies the knowledge).
- *Nurturing:* assisted recreation of tacit knowledge.

Motivating Activities

Strictly spoken, motivating is not a knowledge activity, but an enabler. However, we have included it in the KI Watermill model because it cannot be ignored, since motivation is a precondition for all the other activities: *Motivating:* prompting people to buy in and to apply knowledge activities intrinsically for their own good.

The meaning and impact of these eight activities will be made clear throughout this book, starting with the next section.

2.5 KI Problems and Solutions

A major challenge for companies is to recognize and solve problems they encounter during their work. The development of new products is not without problems. A considerable proportion of new products are not being developed in time, within costs, or meeting the original targets of quality and technical performance [5]. Although there are many potential causes for these problems, part of them is undoubtedly caused by KI deficiencies, for example, by a failure to trace back knowledge that has been in the company.

To illustrate the type of KI problems that can be encountered during NPD, Table 2.4 (see next page) gives descriptions and examples of problems with each of the eight activities described in Sect. 2.4.

For solving these problems, numerous amounts of solutions exist. There are techniques, such as brainstorming and story telling, but also IT-based tools, such as search engines, databases and expert systems. A solution, as in "we did such and such to solve this KI problem", is just as valuable (or even more so) for SMEs as is "we used that particular technique to solve this KI-problem". Since tacit and latent knowledge seem to be more relevant for SMEs than explicit knowledge is (see Sect. 2.2), these more 'soft' solutions are most likely to be even more significant for them.

Solutions for KI problems are not only solutions when their vendors or original inventors have labelled them as such. On the contrary, every solution that can solve a KI problem can be labelled as a KI solution. For example, a project planning software tool is not designed to support KI. However, if such a tool appears to be of great value to an SME in, for example, their process of acquiring knowledge from another company, it is in fact a KI solution. Rather than summarizing a number of solutions in this chapter, we have dedicated Chap. 4 of this book to describing and classifying types of solutions that exist for the problems mentioned in Table 2.4. Moreover, Chaps. 5-10 provide detailed examples of practical solutions for each of the eight problem types.

No matter how simple or sophisticated some solutions are, the road from KI problems to KI solutions is a difficult one. Although by no means can we provide a clear-cut step-by-step guide for KI problem solving, there are three separate steps:

1. Companies must identify and define a KI problem. After all, in order to look for solutions, they have to know what problem to solve.
2. They have to search for an effective solution that is expected to solve their problem. This can be solutions that need to be customized or even completely developed for the company, but also commercial off-the-shelf solutions.
3. This solution needs to be implemented and used in the company, after which it can be evaluated as to whether and to what extent it has solved the problem.

Table 2.4. Definitions and examples of problems with knowledge activities

Activity	Problems
Elicitation	Although it could be done, knowledge is not expressed to such a degree that it is understandable for others.
Examples	- Knowledge is not made explicit. - There is knowledge available somewhere, but it is 'under the surface'. - There is a vague idea of what is going on, but it is not known exactly.
Codification	Knowledge is not codified: there is explicit knowledge available, but it resides within people and thus cannot be transferred independently of them.
Examples	- Although it could be written down, people do not do it. - It is hard to capture best practices into new procedures. - Knowledge cannot be shared without personal contact.
Detection	Knowledge that is needed in a certain situation or its source is not found.
Examples	- Not being able to find knowledge because it is scattered or hidden. - There is so much knowledge available that it is hard to stay informed. - Not knowing what sources are the best for certain knowledge.
Assessment	Being unable to assess the value, significance, or meaning of knowledge. Although available, it is not known what its use is or why it is needed.
Examples	- Having a lack of knowledge about the real advantages of new knowledge. - There are no criteria to evaluate the knowledge. - It is unclear whether knowledge/sources are reliable or complete.
Transfer of knowledge	Although it is known where relevant explicit knowledge can be found, for some reason it cannot be transferred from the source to the company.
Examples	- Being unaware of the fact that tacit knowledge is not transferable. - Substituting technological contact (e.g. the Internet) for human interface. - Lacking a shared platform by which knowledge can be transferred.
Transfer of knowledge holder	Not being able to transfer, hire, employ, or keep people with valuable knowledge within the company.
Examples	- Being unable to get personnel with the right skills or knowledge. - People with unique knowledge leaving the company. - Finding someone relevant, but being unable to get them to the company.
Nurturing	Not being able to provide knowledge that is highly based on experience.
Examples	- Knowledge of senior staff is hard to transfer to junior staff. - People are unable to express all the subtleties of their work. - Some people are indispensable: once they leave, their knowledge has gone.
Motivation	Although certain activities can be done, they are not done, because people are not motivated or willing to do them or not rewarded for doing them.
Examples	- Knowledge is not shared because it is considered too valuable to share. - People do not take the time to properly archive their knowledge. - Not-invented-here syndrome: unwillingness to use knowledge from others.

The fact that the solution is to be implemented in the company means that it should not only fit the problem, but also the company and its strategy mode. Fitting the company means that a solution has to be suitable for a high-tech SME, e.g. in terms of costs, ease of use, organisational fit, and maturity. There are three basic strategy modes for dealing with problems [12]: problem preventing, solving, and setting. When a *problem preventing* strategy is applied, a firm acts under the basic assumption that what was right for yesterday will be right for tomorrow as well. *Problem solving* is an evolutionary approach in which problems that appear

are solved as long as solutions are in line with the current situation in the company. *Problem setting* is more revolutionary and involves finding solutions to problems before they actually occur. The strategies and the criteria for SME suitability are further explained in Chap. 4. Chap. 11 provides an example of how this problem-solution matching process can be supported by an Internet portal.

2.6 Summary and Conclusions

Chap. 1 has shown the importance of KM for SMEs and has explained why KM in SMEs is distinct from KM in large companies. That chapter has argued that one of the most striking differences is SMEs' need to acquire and use external knowledge. Consequently, in this chapter we have further specified the concept of 'knowledge integration' (KI) and have provided a concise overview of KI theory that is relevant for SMEs. Of course, this overview is not complete. However, it defines and exemplifies the most important concepts, which are:

- Types of knowledge: there are three general types of knowledge (explicit, tacit, and latent) and three NPD-specific categories of knowledge (customer/market, technological, and organizational).
- Sources of knowledge: these can be characterized by dichotomies (internal-external, personal-impersonal, formal-informal, nearby-remote), and consist of a wide range of sources (including customers, suppliers, and fairs).
- KI process: this consists of eight activities (elicitation, codification, detection, assessment, transfer of knowledge and knowledge holder, nurturing, motivating) that are used in three stages (identification, acquisition, utilization).
- KI problems and solutions: there are KI problems and KI solutions associated with the eight knowledge activities and with the three KI strategy modes.

With these theoretical elaborations on KI, a central question arises: How do SMEs execute KI in NPD practice? In order to answer that question, the next chapter discusses the results of an international survey on KI amongst high-tech SMEs. Subsequent chapters provide practical examples of specific parts of the models that were outlined in this chapter. At the end of the book (Chap. 13) we come back to this chapter and discuss how these concepts have been used in practical KI.

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