Understanding planning for effective decision support
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CHAPTER 3

THE METHODOLOGICAL FOUNDATION
AND
THE RESEARCH APPROACH

3.1 INTRODUCTION

The present chapter discusses the methodological foundation and the research approach used to find an answer to the research questions addressed in this study. The research questions determine the requirements for the research approach. Firstly, understanding the knowledge and rules in the nurse scheduling domain requires an empirical research approach. This is related to the scientific aim of the study. Secondly, there is a need to investigate the knowledge and rules of the scheduler in a practical setting. The results illustrate the practical relevance of the study. The combined play of theory and practice will continuously be attended to in this study. The capriciousness of a practical setting along with the methodological strength of scientific research bear upon the character of this study. This is a challenge which may well be typical of research in the field of management and organization.

The empirical research as applied in this study is anchored in the behavioural sciences. The empirical approach is explained by discussing two relevant methodological models, viz. the empirical cycle (de Groot, 1961) and the regulative cycle (van Strien, 1975, 1986). It involves reflecting on the value of scientific statements on the one hand and providing more practical guidelines for researchers on the other hand. The former concerns primarily the way of reasoning that is related to the more philosophical aspects of methodology (see Hofstee, 1980; de Groot, 1961; Koningsveld, 1976; Lakatos, 1970; Popper, 1959; van Strien, 1975). The latter concerns the practical guidelines that deal with method and techniques that are necessary to organize research efficiently and effectively (see Meerling, 1980; Neale & Liebert, 1980; van der Zwaan, 1990).

My research closely follows both the empirical and regulative cycle in order to make recommendations for an effective decision support design based on understanding human planning. Such a use of the two cycles in one study could increase the value of research in the field of management and organization. This is further elaborated by discussing the two models first and then examining their possible role in the discipline of management and
organization in general.

3.2 THE EMPIRICAL CYCLE AND THE REGULATIVE CYCLE

The empirical cycle will be discussed first. The empirical cycle aims at developing theories within a dominant paradigm. A theory refers to a body of knowledge consisting of a particular number of coherent rules. A theory is used for prediction and explanation of relationships among variables. It is attained by testing hypotheses with empirical data in order to reach general statements. The empirical cycle represents the hypothetical-deductive research approach. It includes several phases which are depicted in figure 3.1.

In the observation phase the emphasis is on the collection of empirical facts. In the next phase, induction, the aim is to specify explicitly the hypotheses on the basis of the observed facts. Hypotheses need to be defined in measurable variables in order to derive concrete predictions. This is the main focus in the deduction phase. Next, these predictive statements are checked in the testing phase by collecting new empirical data in order to examine whether the relationships among variables as predicted can be found in the new data. In the last phase, evaluation, the results are interpreted within the framework of the specified hypotheses and theories. The evaluation phase is interpretative by nature, generating ideas for new hypotheses and research. The evaluation phase runs smoothly into the first phase of
the empirical cycle. Ideally, all phases should be run through in any research and it is worthwhile aiming for this goal. This need not happen in every type of research. Sometimes relationships among variables cannot be predicted because theories are lacking for the problem under consideration. Then the research is mostly of an explorative nature and only some of the phases would be run through. Moreover, the different phases would not be executed separately as presented in the model. The way the empirical cycle is applied depends mostly on the type of research.

Inductive-empirical research applies the empirical cycle in a strict sense following the requirements of the scientific method, while other types of research, such as descriptive research or explorative research, apply only one or a few of the phases, mostly in a less strict order (de Groot, 1961). The emphasis in these last two types of research is on the first two phases, observation and induction. Because of lacking theory and insight into the nature of the problem, the researcher is not able to specify the relationships between variables as clearly. On average it is difficult or even impossible to specify hypotheses beforehand. The research questions put forward in explorative and descriptive research are therefore not aimed at testing hypotheses. Naturally, on the basis of the results hypotheses could be specified afterwards which can then be tested in research. Descriptive research stresses the description of a variable whereby the relationships between variables are subordinate (Janssens, 1982), whereas in explorative research the researcher has suppositions about the nature of the problem. Both explorative and descriptive research address understanding such variables as measured in these types of research. It can be considered a first step in validating concepts. This study uses explorative research. This means that variables and relationships among variables which describe the manual performance of a planning task can not be determined in advance.

The last characteristic aspect of the empirical cycle is that the researcher is a spectator who is not a part of the problem being studied by means of personal involvement. This implies that there is a separation between the researcher and the research object.

The empirical cycle is a stringent scientific method. The inductive-empirical approach uses the empirical cycle in order to understand and explain problems with the emphasis on the development of theories. In order to fulfil the requirements of the approach an artificial situation is created which often bears little resemblance to a natural situation. In such a case the empirical cycle would not seem workable for all types of research. Difficulties may arise when the problem being studied is embedded in a natural setting. This is the case for this study. Often such a problem does not conform to the rigidity of the research model. Despite striving to follow the cycle as strictly as possible, the researcher needs to make some concessions in the use of it. Unexpected things might happen because of which a strict control on collecting data cannot be maintained or because of which a person cannot spend as much time taking part in the research. In addition, the aim of the research could be that a problem needs to be solved by generating a concrete solution. In practice many problems exist which need to be solved by a realistic design; for example, a decision support system
needs to be designed to support a planner, or a method for organizational diagnoses needs to be developed to help a manager. Typically the result of such research is that some intervention in practice will take place. The empirical cycle does not deal with this aspect.

Van Strien (1986) developed the regulative cycle which aims at intervening into practice by making a plan in which the focus is on solving an individual problem in particular circumstances. There will be a clear client organization which has a problem and which is involved during the whole cycle. This means as well that the researcher is also involved with the problem situation. The problem situation and the research are influenced by each other. The developed plan is often only suitable for that specific situation. In this respect the regulative cycle does not aim at general statements or at developing theories. The important criterion is the adequacy of the solution. However, it could be tentatively defended that a theory about a design for solving a problem has been developed. Also, the choices made in the development of the design are justified by arguments and rules.

The regulative cycle consists of the following phases as depicted in figure 3.2.

The first phase comprises the identification of a problem which is further diagnosed in the second phase. In the next phase a plan is developed in order to solve the problem. In the intervention phase the plan is implemented in practice, which is evaluated in the last phase in order to check whether the problem has been solved. This phase may lead to new problems which means that the cycle starts again. The first three phases in the regulative cycle are characterized for the most part by thinking, whereas the last two phases consist of doing. It is sensible to display a critical attitude by reflecting on the results of performed acts. Moreover, the transformation between two phases, from a diagnosis to a plan, takes place through theoretical reflections.
The regulative cycle is normative in the sense that the development of a design or plan is guided by an objective derived from the problem under consideration. Next, the developed plan functions as the norm for solving the problem. This normative character is included in each phase because there is a problem which needs to be solved in order to create better conditions. For example, the problem solving is directed by an organization model. The regulative cycle could therefore be useful for design-oriented research.

The stringency of the scientific requirements as in the empirical cycle could hardly be met because of the immediately active character of the regulative cycle. This means that the situation being studied is continuously involved in the research process. The researcher cannot just step out of the situation.

An overview of the differences between the empirical cycle and the regulative cycle is given in table 3.1.

It should be noticed that these two models lie at both ends of a continuum. Although these two models are mostly separately applied in research, de Groot (1961) and van Strien (1975) both indicate a relationship between the two different models: a theory as result of the empiric cycle can be processed in phases of the regulative cycle in order to act effectively. In this sense these two cycles benefit from each other. Moreover, theoretical insights are transformed into practical usability, and feedback from the design in practice stimulates a better understanding of theories. Besides being able to use the results of each cycle within the other cycle, it would also be possible to integrate (phases from)
Table 3.1  COMPARING THE TWO RESEARCH CYCLES

<table>
<thead>
<tr>
<th>the empirical cycle</th>
<th>the regulative cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>explaining</td>
<td>acting</td>
</tr>
<tr>
<td>theory</td>
<td>design</td>
</tr>
<tr>
<td>predictive</td>
<td>normative</td>
</tr>
<tr>
<td>researcher is spectator</td>
<td>researcher is actor</td>
</tr>
</tbody>
</table>

the empirical and regulative cycle within one research project. This could be achieved, for instance, by executing the *observation* and *induction* phases and thereupon grounding design guidelines for decision support. This refers to the *plan* phase. The *observation* and *induction* phases act as substitutes for the *problem* and *diagnosis* phases. This study uses a comparable integration of different phases from the two cycles.

3.3  THE ROLE OF THE EMPIRICAL AND REGULATIVE CYCLE IN THE DISCIPLINE OF MANAGEMENT AND ORGANIZATION

The discipline of management and organization cannot lean upon a research paradigm of long standing. The research object concerns the processes of management and organizations to be viewed from an interdisciplinary problem-oriented view and directed to management (de Leeuw, 1991). Defining the scope of research has consequences for the structure of the research. First of all, the influential role of the problem owner's links with the organization being studied must be taken into account. It is namely a perceived problem. Research will therefore often originate in an actual problem situation. Consequently, the practice of the organization has a great impact on the structure of the research. In solving the problem the main focus is on the practice and thus the role theory plays is of minor importance. The research process is merely guided by qualitative data and subjective judgments, though from a multidisciplinary point of view. Second, the researcher would not be an outsider any more. He/she is personally involved in communication with the problem situation. Third, the aim of research is to deliver so-called knowledge products which can be applied to solve the problem (de Leeuw, 1991), knowledge products which should be suitable for use in the organization in future, such as, for instance, a method for understanding management processes.

It is not surprising that the most frequently applied type of research is design-oriented
The methodological foundation

Research (Eynatten, 1989; den Hertog & van Assen, 1988). This type of research is addressed to design organizations in the broadest sense: for example, the implementation of a management information system, development of product innovations, and adaptation of organizational changes. Design-oriented research is based on the regulative cycle, whereby attention to the empirical cycle has been neglected. Consequently, the development of theories and generic knowledge about organizations will be moderate. The choice to emphasize the utility of the regulative cycle, whereby the empirical cycle is put aside, is prompted by de Leeuw (1991, p. 19) who states that the empirical cycle is hoofdzakelijk relevant bij zuiver wetenschappelijk onderzoek. De Leeuw's opinion regarding the great distance between the empirical and the regulative cycle does not agree with those of de Groot and van Strien. When starting research with the aim of finding a concrete solution for a problem the one-sided emphasis on design-oriented research is understandable; however, it does not justify paying less attention to the scientific point of view. Moreover, a synthetic research approach consisting of a scientific method in combination with design-oriented research has been advocated in the discipline of management and organization. Volbeda's recent thesis (1992) as well as this thesis are examples of such a synthetic approach in which theories determine part of the research process. By following the scientific approach the role of the problem owner will be less influential in doing research, though practice imposes specific requirements which are difficult to keep under control due to uncertainty and lack of time. In spite of this it should be a challenge and a necessity to maintain a scientific approach in the discipline of management and organization. If the empirical cycle is abandoned, then the building of theories is left to coincidence and the knowledge derived is founded on obscurity. Actually, the choice of a specific type of research should be postponed and it should be guided more by the nature of the research questions instead of by the problem owner.

In this study the starting point concerns the problems the scheduler has with making schedules in daily hospital practice. The practical issues are interpreted using insights from problem-solving theory in order to formulate the research questions. The role of the scheduler as the problem owner has first been put aside, because the aim was to acquire insight into scheduling that can be applied to other hospitals as well and that can be used for the design of the computerized nurse scheduling system. By choosing a specific research design (see 3.4) it is possible to derive recommendations for effective decision support.

### 3.4 RESEARCH DESIGN

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1 is mainly relevant in pure scientific research
The execution of the different phases of the two cycles is supported by available methods and techniques. Which methods and techniques have been applied is described in the research design. The design of a research study determines its validity, whether it can reasonably be transplanted to other situations. Besides the external validity, the internal validity signifies that the measurements can be ascribed to the effects of the manipulated (independent) variable (Neale & Liebert, 1980). It is important therefore that the research be performed in a controlled setting. In order to make comparisons between different situations a quasi-experiment was chosen which contains two different experimental settings and different groups of subjects. The collection and the interpretation of data measured in the two settings is served by the cognitive task analysis. The present paragraph reports the research design applied in this study.

3.4.1 Three groups of subjects

Several hospitals participated in the DISKUS project. Some of them cooperated in this research by offering scheduling expertise. Eighteen subjects agreed to participate in this study after receiving an explanation of its purpose. They were classified as either an expert or a novice in the field of nurse scheduling on the basis of their experience with this task. The expert group consisted of six head nurses who were acquired from two hospitals. All of them had performed the monthly-recurring task for longer than four years. For the most part their knowledge and skills in this field were learned by doing. Although they had access to practical handbooks on nurse scheduling, these books were consulted only occasionally.

The novice group consisted of twelve student nurses who were all studying at the same school: six of them had already gained practical experience in their future profession while the other six student nurses only had theoretical experience with nursing. These two groups were denoted respectively the novice-practical training (novice-p) and novice-no practical training (novice-np) group. None of them had ever performed a nurse scheduling task and in case of the novices-p, they only knew this domain by being scheduled during their practical training periods.

Except for four novices who finished their education at the school for nursing, all participants were involved in both studies where the nurse scheduling task was investigated in the manual situation and under conditions of decision support.

3.4.2 Mixed design

The study consisted of a mixed design which, in accordance with Neale and Liebert
The methodological foundation 55

(1980), was designed so that the three groups did not overlap. This implies that the subjects of the expert group and the two novice groups were not interchangeable with respect to their experience in the field of nurse scheduling because the experts were familiar with this task and the novices were not. This means that the degree of experience was a subject-related variable. It also means that there is not a control group as required in an experimental setting. Lastly, the subjects did not receive a particular treatment but are placed in two different settings. This study is therefore regarded a quasi-experiment.

The task performance of the scheduler, i.e., the dependent variable, was investigated under the different conditions of the scheduling task, i.e. the manipulated variable. The schedulers made a schedule in the manual scheduling condition first. About one year later, or sometimes more, the scheduler made a schedule in the decision-support condition. The nurse scheduling system was built during the intervening period.

A mixed design yields within-subjects comparisons of the expert group and the novice groups as well as between-subjects comparisons (Table 3.2). Therefore, a mixed design reveals the general applicability of the experimental effect of the manual and the decision-support conditions.

The number of participants is indicated in the cells.

3.4.3 Cognitive task analysis

Cognitive task analysis (Roth & Woods, 1989) is the method used to reveal
the knowledge and rules of the expert and novice subjects. Those knowledge and rules are elicited that underlie the task performance when the subject makes a schedule. It sets up the data for interpretation within the framework of problem-solving theory. In addition, it results in an interpretation of the cognitive demands of the scheduling task. The cognitive demand refers to the cognitive processes which are required when a task performer accomplishes a planning task and it is determined by the complexity and difficulty of such a task. This is in accordance with Roth and Woods (1989, p. 247): 'a cognitive task analysis is used to derive a description of the cognitive demands imposed by a task and the sources of good and poor task performance'. These ‘sources’ refer to the knowledge and rules of a scheduler that influence the level of the task performance. Thus, the outcome of a cognitive task analysis is a generic model of cognitive processes on which the design of decision support should be based (Rasmussen, 1986).

A cognitive task analysis comprises both a knowledge acquisition and a knowledge representation phase, but for the most part it concerns the first one. Before explaining in more detail the knowledge acquisition phase, which is stressed in this thesis, I will briefly describe the knowledge representation phase. Knowledge representation as part of the cognitive task analysis means a formal presentation of knowledge in production rules, frames or scripts, semantic networks, or conceptual graphs (Jorna, 1992; Luger & Stublefield, 1989). This phase is an important phase in building knowledge-based systems because it is the transformation to the implementation phase (Luger & Stublefield, 1989). 'Knowledge representation’ in this sense should be distinguished from 'representing knowledge’, which is comparable with knowledge modelling. The meaning of 'knowledge’ in 'representing knowledge’ refers to the carrier of knowledge, a human cognitive system. Knowledge in computerized systems differs from knowledge in human cognition: the latter could be uncertain and incomplete or even contradictory, whereas the same would cause problems in computerized systems (Jorna, 1989, 1992).

The knowledge acquisition phase embodies a systematic approach to gathering and interpreting different types of knowledge. In the field of Artificial Intelligence this phase is often denoted as the most essential phase for building knowledge-based systems and expert systems (Hayes-Roth, Waterman & Lenat, 1983; Luger & Stublefield, 1989). Presently,
The methodological foundation

Knowledge acquisition is also becoming more influential in the field of management decision making (Paul & Doukidis, 1986; Kim & Courtney, 1988).

The aim of knowledge acquisition is to obtain and structure systematically the knowledge of an expert (Wielinga, Bredeweg & Breuker, 1988). In this study knowledge acquisition is also applied in the case of the novices. Knowledge acquisition is performed by a number of steps. In the first step the emphasis is on acquiring insight into the problem. On the basis of this insight the knowledge and rules are more systematically investigated in the second step and in the last step the elicited knowledge and rules are interpreted and properly described. These three steps are respectively denoted as problem formulation, knowledge elicitation and knowledge modelling, and are further discussed below. The person in charge of a knowledge acquisition phase is called a knowledge or cognitive engineer. He or she is responsible for performing adequately these three subphases when investigating the knowledge and skills as well as for revealing the cognitive demands in a specific domain. This is often considered a time-consuming and difficult job.

The first phase of knowledge acquisition: problem formulation

The problem formulation phase is a generic orientation in the domain to begin the knowledge acquisition. The aim of the problem formulation phase is to portray a general overview of the domain under consideration embedded in the organization besides the environment of the task. It concerns forming an impression not only of the information needed to perform a specific task and of the various problems met by practitioners, but also of the organizational context of the domain under consideration. Consequently the researcher becomes acquainted with the domain under consideration as well as with the planner. The task performance of the problem solver is only slightly under consideration because this is the main object of the next phase. The results of the problem formulation offer insight into the domain which is processed in a design for the knowledge elicitation phase. Herewith analysis of the domain and the task performance are not performed in isolation. The unstructured interview is a good tool for investigating the domain in as unbiased a way as possible by asking broad and open questions. A design for the knowledge elicitation phase is based on the results of this phase. Knowledge elicitation is focused on the task performance.

Second phase of knowledge acquisition: knowledge elicitation

The knowledge elicitation phase applies several knowledge elicitation techniques in order to elicit the knowledge and rules of an expert or novice efficiently. Knowledge elicitation techniques differ from one another in the type of knowledge elicited. For example, an interview elicits knowledge of objects and relations among objects in the domain, whereas a thinking aloud protocol uncovers the reasoning processes underlying the task performance in a special domain. This means that not every technique is equally suitable for eliciting all types of knowledge. Therefore it is recommended that more than one knowledge elicitation
technique to be applied the domain under consideration. Several readable overviews have been written about knowledge elicitation techniques by Burton and Shadbolt (1987), Boose and Gaines (1990) and van der Werff (1992). We applied three of these knowledge elicitation techniques.

The following three knowledge elicitation techniques were employed in this research: interview, observation of the task performance, and thinking aloud protocol.

**Interview**

The interview is used to obtain a general overview of the content and the nature of the domain under investigation as well as a description of the objects in this domain and the specific problems met (Bainbridge, 1985; Davies & Hakiel, 1988; van der Werff, 1992). It goes further into the matters mentioned in the unstructured interview by asking specific questions about those subjects. However, the value of the interview is limited because it does not result in a complete understanding of how knowledge is used during task performance. Other knowledge elicitation techniques are chosen in order to complete the picture.

**Observation of the task performance**

This knowledge elicitation technique is used to understand the actual performance of the task. Each scheduler is observed in the hospital when he or she is making a schedule for the ward. At the same time, the scheduler is asked to think aloud in order to reveal his or her reasoning processes. If needed, questions about the performance of the task are asked, for instance, in the case of scheduling the evening shift, asking why a specific nurse is assigned to that shift. Interrupting the scheduler should be restricted, however. The advantage is that a realistic insight into the specific problems of the ward are acquired in this way. There are two restrictions to using the observation of the task performance. Firstly, a precise comparison among the different schedulers cannot be made because of the differences in their wards and thus, in their specific scheduling problems. Secondly, observing the task performance gives a limited insight into the cognitive processes. From a methodological point of view it is not possible to control for artifacts, in contrast to an experimental situation. In order to investigate more precisely how the scheduling task is performed, a thinking aloud protocol was chosen.

**Thinking aloud protocols**

"Thinking aloud" is a useful knowledge elicitation technique for exploring the cognitive processes underlying the task performance of an expert or novice (Breuker, Elshout & van Someren, 1986); therefore, the thinking aloud protocol has been a generally accepted technique in research on problem solving for many years (Newell & Simon, 1972; Ericsson & Simon, 1984). In the thinking aloud protocol people are asked to speak aloud what they think while solving a specific problem. In other words an attempt is undertaken to verbalize the cognitive processes. (Elshout & van Leeuwen, 1992). Thinking aloud synchronizes thus
with the cognitive processes. This differs from introspection where the cognitive processes have to be retrieved afterwards from memory. Verbalizations in a protocol are therefore more reliable. Another point is that when the task is well known to the subject, an accurate verbal report is obtained (Nisbett & DeCamp Wilson, 1977). Moreover, the thinking aloud protocol as a method gains power when offering a manipulated task, especially when such a task is offered to groups with different levels of expertise (Roth & Woods, 1989). Hayes-Roth and Hayes-Roth (1979) have already acquired experience with thinking aloud protocols in their research on a planning task for doing errands.

The ‘thinking aloud’ is tape recorded and transcribed literally afterwards. The outcome is thus a written document on which further analysis needs to be done, so-called protocol analysis. This gives an enormous amount of data which needs to be managed accurately. Often the interpretation of protocols is an iterative process (Bainbridge, 1985). On the other hand, the validity of a protocol analysis appears to be high. An elaborate description of the use and interpretation of thinking aloud protocols and a protocol analysis can be read in Newell and Simon (1972), Nissbett and DeCamp Wilson (1977) and Ericsson and Simon (1984).

**Third phase of knowledge acquisition: knowledge modelling**

The interpretation of the gathered data in the knowledge elicitation phase is realized in the knowledge modelling phase. The aim of knowledge modelling is to build a model of expertise which describes knowledge and rules involved in the task performance.

An interpretation scheme is needed to guide the process of structuring knowledge and rules adequately. The four-layer framework as distinguished in the KADS (Knowledge Acquisition and Documentation Structuring) methodology is useful for the further interpretation of the protocols (Wielinga, Schreiber & Breuker, 1991). KADS has been applied for describing diagnostic tasks. I consider KADS as a coding scheme to analyze the thinking aloud protocols.

This four-layer framework corresponds with four distinctive types of knowledge, respectively: *domain knowledge, inference knowledge, task knowledge and strategic knowledge*. This is depicted in table 3.3.
Table 3.3 KNOWLEDGE CATEGORIES OF EXPERTISE IN THE KADS FOUR-LAYER MODEL

<table>
<thead>
<tr>
<th>knowledge category</th>
<th>elements</th>
<th>relationships with other knowledge categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>strategic knowledge</td>
<td>strategies, meta-knowledge</td>
<td>controls task knowledge</td>
</tr>
<tr>
<td>task knowledge</td>
<td>task / goals</td>
<td>applies to inference knowledge</td>
</tr>
<tr>
<td>inference knowledge</td>
<td>knowledge sources, meta-classes</td>
<td>describes domain knowledge</td>
</tr>
<tr>
<td>domain knowledge</td>
<td>concept relationships</td>
<td></td>
</tr>
</tbody>
</table>

Domain knowledge contains static knowledge of the domain such as objects, properties, and relations between objects, for example, a nurse is either qualified as 'experienced' or 'inexperienced'. Further on, the domain layer is used by the so-called inference layer which contains inference knowledge. This type of knowledge processes objects from domain knowledge. Inferences refer to the basic actions of a domain as well as to the role of the domain objects. Examples of inferences are 'selection', 'abstraction', and 'refinement'. Special types of inference knowledge are knowledge sources and meta-classes. Wielinga, Schreiber and Breuker (1991) defines these as follows: 'A knowledge source performs an action that operates on some input data and has the capability of producing a new piece of information (knowledge) as its output' (p. 14) and 'A knowledge source operates on data elements and produces a new data element' which is called a meta-class.

The task layer applies knowledge of the inference layer in order to attain the goals of a task. Task knowledge therefore controls how a goal is accomplished. The task layer contains knowledge of elementary tasks, which are defined by Wielinga (p. 18) as follows: 'a task is a composite problem-solving action'. Further on, task knowledge consists of task, control terms and the task structure. The task structure is a decomposition into subtasks.

The strategic layer controls the task layer and it contains strategic knowledge which 'determines what goals are relevant to solve a particular problem' (p. 21). The dynamic planning of the task execution is therefore organized by strategic knowledge. The model of expertise in KADS is a competence model. The KADS methodology does not provide an explanation of cognitive processes, which, in this study, is considered a restriction.
3.4.4 Procedure

The three phases of the knowledge acquisition belonging to the cognitive task analysis are part of the quasi-experiment. This is depicted in table 3.4.

The phase of problem formulation was only performed in the expert group under the manual condition, while the knowledge elicitation and knowledge modelling were performed for all subjects under both conditions.

In table 3.5 the sequence of knowledge elicitation techniques used in the knowledge acquisition phase are depicted for both the expert and novice groups. The unstructured interview, which was only performed in the expert group, focused on the role of nurse scheduling in the hospital in order to become acquainted with the nurse scheduling domain. Furthermore a structured interview was performed which comprised questions about the most relevant aspects of the nurse scheduling domain. The experts were interviewed twice for the problem formulation phase, the interviews taking about two hours each, whereas the interview with the novices took about 30 minutes and they were interviewed just
Table 3.4  DESIGN OF THE QUASI-EXPERIMENT

<table>
<thead>
<tr>
<th></th>
<th>manual condition</th>
<th>decision support condition</th>
</tr>
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<tr>
<td></td>
<td>experts</td>
<td>novices</td>
</tr>
<tr>
<td>problem formulation</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>knowledge elicitation</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>knowledge modelling</td>
<td>yes</td>
<td>yes</td>
</tr>
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</table>

once, and less extensively, prior to the manual performance of the nurse scheduling problem. The interviews were performed by different interviewers.

The observation of the task performance was done to comprehend how the expert was making a schedule for his or her own ward. Based on the data derived from the interviews and the observation of the task performance, a manipulated task, i.e. a scheduling problem (see 3.4.6), was made for the actual thinking aloud protocol.

Table 3.5  KNOWLEDGE ELICITATION TECHNIQUES USED

<table>
<thead>
<tr>
<th></th>
<th>unstructured interview</th>
<th>structured interview</th>
<th>observation</th>
<th>thinkout aloud protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>experts</td>
<td>novices</td>
<td>experts</td>
<td>novices</td>
</tr>
<tr>
<td>problem formulation</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>knowledge elicitation</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>knowledge modelling</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
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</table>

The actual quasi-experiment was run either in the private offices of the head nurses (the expert group) or for the novice groups in a quiet classroom at school. All subjects were asked not to exchange any information about the presented scheduling problem during the period the experiments took place.

The written scheduling problem was presented and the participant was asked to make a conclusive schedule. All the necessary information needed to generate a schedule had been offered. Each subject had as much time as was needed for making his or her definite
schedule. During the task performance the participants were asked to think aloud, and this was recorded on tape (thinking aloud protocol) at each session.

### 3.4.5 Statistical analysis

A number of tests were used for the statistical analysis of the data. The Kruskal-Wallis test aims at testing whether the scores on a variable differ between groups. This was used when there were more than two groups. The variable should be measured on the ordinal level. The population to which the groups belong need not fulfil the normal distribution and the variances need not be the same either. When there were only two groups of subjects then the Mann-Whitney-u-test was used. The Fisher-exact-test can be used to test the independence between variables. The scores are expressed in frequencies in a $2 \times 2$ table. The F-test was used to test whether the variance between the groups of subjects differs for a variable whereby the alpha needs to be chosen.

### 3.4.6 The scheduling problem

The scheduling problem offered to the subjects concerned a ward in a general hospital where sixteen registered nurses and five student nurses were working. All the data were derived from a real situation except for the names, for which fictitious names were substituted for reasons of confidentiality. The task of the scheduler was to make a schedule for a one-month period. An over-view of the characteristics of the registered and student nurses was presented with regard to full-time or part-time work, their function and their quality (expressed as more versus less experienced for the registered nurses). The student nurses were first through fourth year students. The ward was supervised by one head nurse and one deputy nurse. The quantitative staffing of the day, evening, and night shifts was presented as well as the staffing in the weekends. Additional information concerning recent night shift history, weekends off, courses, wishes, general agreements and vacation for each nurse was also given. All data were presented on written notes in advance, including an empty framework for a schedule, together with different coloured felt pens, as well as the different codes of each shift. The same scheduling problem was used with the ZKR system in the decision support setting.

### 3.4.7 The research design of this study
An overview of the research design applied in this study is given in figure 3.3.

This figure shows all knowledge acquisition phases that were passed through in this study and the data provided by each step. The boxes labelled 'manual' will give the answer to the first research question about the task performance, whereas the boxes labelled 'decision support' as well as the comparison between 'manual' and 'decision support' give answers to the second research question. The other three boxes refer to the answers to the last research questions. The top boxes refer to the first two phases from the empirical and the regulative cycles, viz. the observation/problem phase and the induction/diagnosis phase. The central part elaborates further on them whereas the right part of figure 3.3 is the working out of the design phase of the regulative cycle.