Chapter 3
Mapping prior knowledge:
A conceptual map of prior knowledge and an account for research into the domain-specific prior knowledge

Introduction

Before defining the concept 'prior knowledge', it seems interesting to take a look at the 'knowledge' terminology in literature.

Despite the numerous terms in use relating to prior knowledge, explanations of these terms are few and far between, and when they are given, they are too general and vague to be of much use. For example, when Neisser (1976) talks about the role of prior knowledge in perception, he describes prior knowledge as "the skills and experience of the observer" or, further, as "what he knows in advance". Marr and Gormley (1982) describe prior knowledge as "knowledge about events, persons, and the like which provide(s) a conceptual framework for interacting with the world". Generally speaking, definitions of prior knowledge to be found in the literature are little more explicit than the two examples given. An exception to this is the study of Bloom (1976) using the concept 'cognitive entry behaviours'. With this concept Bloom refers to "those prerequisite types of knowledge, skills, and competencies which are essential to the learning of a particular new task or set of tasks". By means of our study, we could ascertain that vagueness and pluriformity of concepts is not only a problem in general educational research, but also in domain-specific research such as research into economics education (see chapter 4). The lack of precision in defining what is meant by prior knowledge and its related concepts can have serious consequences for research since researchers' and readers' interpretations of such knowledge-related constructs can have significant effects on

reported results. We would argue that only through an exploration and conceptualization of various types of knowledge, empirical research into the phenomenon can be advanced significantly.

A study was made of the literature, plus a study involving Dutch and Flemish scientists, which had four main aims:

1. to examine the terminology associated with prior knowledge;
2. to examine that terminology as used by experts in the field of cognitive psychology and artificial intelligence;
3. to construct a conceptual map of prior knowledge terminology that may improve understanding and promote future research; and,
4. to develop definitions for the key terms to provide a basis for our further research.

First, we will comment on the use of prior knowledge terminology and the problems associated with this. We will give our views about categories of and differences in prior knowledge. Further, after defining the basic terms, we will propose a conceptual map of prior knowledge. Finally, we will try to come to a valid indexation of prior knowledge by reference to scientific judgements, in order to end up with a an indexation and operational approaches to measure prior knowledge. Taking the data from the literature review and from an enquiry among experts into account, we focus in the last part of this chapter on the domain-specific prior knowledge.

A conceptual map of prior knowledge

Prior knowledge terminology

In order to scrutinize the definitions and the uses made of the concept of 'prior knowledge`, we conducted a literature review. This study showed that clear delineations of the terms used were often missing. We found that in 25 out of 37 studies related to the subject of prior knowledge, no explicit definition was given. Also in our study of the effects of prior knowledge in economics (chapter 4), we found that only a few studies gave an explicit definition. Moreover, Alexander et al. (1990) identified 67 articles published in Reading Research Quarterly since 1980 that referenced one of a family of knowledge constructs in title or abstract. Of those 67, 25 (just over one third) referred to the term 'prior knowledge'. Only 9 of those 25 provided any explicit definition reflecting what the researchers meant by the term. Of course, it may be argued that such definitional statements are unnecessary because the meanings of the terms are commonly understood. However, our study of the literature suggests that even the most basic prior knowledge terms are not consistently defined. We illustrated this earlier by referring to the Neisser (1976) and the Marr and Gormley (1982) definitions of prior knowledge.

Our primary conclusion was that the manner in which researchers use the terminology of prior knowledge to identify their constructs, to state their objectives, and to direct their research activities frequently lacks precision. We cannot be assured, for example, that those who discuss prior knowledge as one of the principal variables in their research are not really testing or treating some more specific dimension of that subsuming construct. In most studies, it is not clear which part of the whole construct the researchers are treating. Likewise, when researchers claim to be investigating domain or discipline knowledge, and when

they fail to define, at least implicitly, what they mean by such terms, then we may need to question the validity of the undertaking (see also the Alexander et al. study, 1990). For instance, we ascertained that in different studies involving domain-specific prior knowledge, the word 'domain' referred to different entities.

Problems revealed by the use of prior knowledge terminology

In the various theories and research on prior knowledge, descriptions and definitions of the terminology are almost exclusively nominal. A great deal is made of the distinction between nominal and real definitions in the indexation and representation of concepts. In nominal definitions, the user introduces the meaning of the term by stipulation. Anyone who does not know the construct is directed towards the meaning within which the construct is used. Nominal definitions of the construct 'prior knowledge' are much in evidence in the literature. They are largely described in terms such as "the totality of knowledge and skills of the subject" or "what he knows already beforehand".

Real definitions are few and far between. Perhaps this observation can be related to another conclusion from this study, that is that prior knowledge thus far has been virtually exclusively measured by means of indicators and by existing tests which were not specially developed for the purpose.

In a real definition, the manner in which the definition of a construct reflects reality is pivotal. The characteristics that the object does or does not possess are given. For example, some authors distinguished between two dimensions: knowledge and skills; others stress the availability or the amount of prior knowledge.

One of the main problems with prior knowledge terminology is that authors use different terms to refer to what appears to be the same construct. In the English-speaking world, in which the phenomenon is most widely studied, various terms are used interchangeably. Prior knowledge is used, but there are also terms such as 'prestorage', 'permanent stored knowledge', 'prestored knowledge', 'knowledge store', 'prior knowledge state', 'prior knowledge state in the knowledge base', 'implicit knowledge' or 'archival memory'. Also 'expertise', 'expert knowledge', 'background knowledge', 'experiential knowledge', 'world knowledge', 'pre-existing knowledge', 'personal knowledge' and 'competence' are used as synonyms. Nevertheless, in most studies the concepts 'prior knowledge' or 'expertise' are used. According to Alexander, Pate, Kulikowich, Farrell, and Wright (1989) for instance, the terms 'domain' or 'domain-specific knowledge', 'content-specific knowledge' and 'subject-matter knowledge' all signify knowledge about a specific field of study (e.g. economics). Still other researchers use a variety of terms, such as 'discipline knowledge', 'topic knowledge', 'background' or 'prior knowledge' to represent what might be better termed as 'domain-specific knowledge'. By contrast, some researchers discuss subjects' prior knowledge or domain-specific knowledge when what they are more accurately referring to is passage-specific, topic knowledge (Langer and Nicholich, 1981).

The review of the literature revealed six categories of problems associated with the usage of terminology related to knowledge terms. Specifically, across studies

a. nominal definitions prevailed over real definitions of prior knowledge related concepts;
b. the knowledge concepts used were mostly not defined;
c. subcategories of knowledge were inconsistently incorporated;
d. different aspects of knowledge were referred to by the same terms;
e. the same aspects of knowledge were referred to by different terms;

f. the interactions among the different aspects or kinds of knowledge were represented differently or ignored.

Categories of prior knowledge

In the research into cognition and learning, the broad term 'knowledge` has been broken down into subsidiary concepts. These categories do play an important role when discussing prior knowledge terminology. A number of cognitivists use the dichotomy of declarative and procedural knowledge, others talk of episodic and semantic knowledge. Still others talk about the use of strategic knowledge. It is possible not only to make a distinction in terms of the content of the prior knowledge, but also in terms of the scope of the area to which it refers. These differences, which origin mainly in research on problem solving, will be explained briefly below.

Declarative knowledge and procedural knowledge

Conceptual knowledge (Posner, 1978), generally called declarative knowledge, is the knowledge of facts, the meanings of symbols and the concepts and principles of a particular field of study. Cohen (1983) even limits this to knowledge of facts, ignoring our constructivist approach. Sometimes propositional knowledge is referred to (Greeno, 1980) or descriptive knowledge (Lodewijks, 1981).

Knowledge of action, manipulation and activities are indicated by De Jong (1986) as procedural knowledge. Cohen (1983) talks of skills, rules, procedures and plans.

The essential difference between declarative and procedural knowledge is that procedural knowledge refers directly to action or activity, while declarative knowledge requires an interpretation in order to lead to action (Messick, 1984). For example, Anderson (1980) distinguishes between declarative and procedural knowledge as "knowing that" and "knowing how" respectively. Cognitive skill is closely related to procedural knowledge and is described as the ability to carry out various intellectual procedures. Anderson (1980) goes on to say that "most declarative knowledge can be expressed verbally while much procedural knowledge cannot.... However, declarative knowledge need not be verbal".
The distinction leads to two currents of scholarly research into 'machine intelligence': to the first, the proceduralists, knowledge is procedural and is concerned with how; and for the second, the declarativists, knowledge includes both propositions ('knowing what') and general procedures to manipulate them.
In our own research we sometimes will differentiate between declarative and procedural test items. This difference, according to the above and based on De Corte's work (1976) on the taxonomy of goals in the cognitive domain, will be operationalized as follows: items measuring the appreciation, the recognition and the reproduction of information will be viewed as declarative; items measuring production or applications (interpretative, convergent, divergent or evaluative production) will be viewed as procedural.

The theoretical distinction between declarative and procedural knowledge is useful in practice since these categories are e.g. helpful to distinguish between experts and novices. Differences between experts and novices can be reduced to the following differences (Jansweijer and Elshout, 1985; Mettes, 1984):

a. Differences in methods of problem analysis.
The novice does not have:
- a variety of models of problem schemata to choose from; or

- an analytical or categorization system for problems.

b. Differences in declarative knowledge:

- this knowledge is more complete and more coherent in the expert;
- the beginner fills in the missing knowledge with naive knowledge and ad hoc theories or idiosyncratic proposals for processes or states.

c. Differences in procedural knowledge:

- the expert has better organized and more wide ranging production schemata, associated with more explicit conditions for application and categories of problem situations;
- the expert's knowledge is structured so that the same information is present at different levels of detail (this applies equally to the declarative knowledge);
- the beginner does not have a systematic solution plan;
- the beginner has problems with the application of general knowledge in specific situations.

Episodic knowledge and semantic knowledge

Episodic knowledge reflects the totality of personal experience in its spatio-temporal context, and is comparable to a historical document. Episodic knowledge is contextual and incidental. Semantic knowledge includes a representation of the external world, abstracted from its context. This knowledge is

largely expressed in terms of 'models of memory' as a system of related concepts, including what are called 'nodes'.

According to Cohen (1983) in practice there is no sharp distinction between these types of knowledge. Each model which makes a distinction must also be provided with an interface between episodic and semantic knowledge. How often do we have to see a leopard to know that its spots are a defining characteristic? 'Permanent stored knowledge' arises on the basis of new episodic inputs.

Using concepts like episodic and semantic knowledge is difficult. In practice the distinction cannot be made clearly. For this reason we shall, in the present study, restrict ourselves to the use of the somewhat better defined concepts of declarative knowledge and procedural knowledge.

Strategic knowledge

Strategy can be seen as a general plan of action in which the sequence of the separate cognitive activities is laid down (Posner and McLeod, 1982). Strategic knowledge directs knowledge acquisition, but the boundaries to the use of this knowledge are thus far unclear. For that reason there are no explicit theories, as yet, on the content of this knowledge (Brown, Collins and Harris, 1978). The conceptualization of this type of knowledge is very vague. Cohen (1983) makes no distinction between this and procedural knowledge. Both comprise skills and plans of action. According to De Jong (1986) the difference resides in the degree of specificity. Procedures related to a small part of the solution process are largely domain-specific, and include algorithms and heuristic devices. Strategies are related to the whole process of solution and are often used more with subject content (Schoenfeld, 1983). There is, however, never a question of a strict dichotomy, but rather of a sliding transition from procedural to strategic.

Experiential knowledge

Further, it has been thought necessary to look at the importance attached to experience as a source of prior knowledge. More research has been directed at the role of experience preceding a learning activity primarily under the influence of the 'experiential learning school' in the US. In the Wagemans and Dochy study (1991) experiential learning is further analysed. It is that part of the prior knowledge which is not formally recorded and which is acquired through life, work and study. Several aspects of this has been shown clearly in research, such as the existence of naive conceptions (Eylon and Linn, 1988), alternative frameworks (Duit, 1987) and student changing conceptions (Marton, 1988; Roth and Anderson, 1988; Johansson, Marton and Svensson, 1985; Dahlgren, 1989). Certainly, we know that all other stated categories of prior knowledge can be partly experiential and thus a representation on our map could only be considered to focus it's importance. A location on the map would therefore be an abstract one.

Tacit and explicit knowledge

Explicit knowledge is knowledge that is currently employed as an object of cognitive activity and is directly interacting with the world along the interface between the learner and what is being learned. It is thus time and situation specific. Explicit knowledge can be used or unused at a certain moment, but at a particular moment and for a particular task, it is all immediately accessible.

Tacit knowledge is not directly interacting through the interface and resides at a deeper level, i.e. is less accessible (Alexander et al., 1990). At a particular moment and for a particular task, this knowledge can be elevated (partly or completely) to an accessible level, though not immediately. For example, not having spoken a

language for years makes it tacit. When used again it may be only half remembered. Tacit knowledge is thus half-remembered knowledge in the sense that it cannot be instantly recalled at the learning 'interface'.

Domain-specific knowledge and domain-transcending knowledge

Recent research has pointed to the fact that both domain-specific knowledge and domain-transcending knowledge exist in the knowledge base (Glaser, 1984). Furthermore, there is evidence that learning is far more domain-specific than earlier theorists of learning believed, i.e. concrete and practical situations seem to be better learning environments than highly abstract ones (Shuell, 1986; Tuma and Reif, 1980). Carey (1985) suggests that the acquisition of knowledge during the total period of development i.e. throughout a person's life, is based on increasing knowledge within various domains. This 'domain-specific restructuring view of development' has received a great deal of support in research on novice-expert differences within various domains (such as physics (Chi, Glaser and Rees, 1982), chess (Chase and Simon, 1973), radiology (Lesgold, Feltovich, Glaser and Wang, 1981) and the social sciences (Voss, Greene, Post and Penner, 1983). Nevertheless it is unlikely that all learning is domain-specific. If this were the case, it would be difficult to explain how individuals deal with new situations or how they handle entirely new information. Viewed objectively, learning, according to Shuell (1986), comprises domain-specific and domain-independent processes. How these processes interact with one another is as yet unclear. Glaser's hypothesis (1984) is that undue emphasis on specific or on more transferable content knowledge in instructions will vary as a function of the prior knowledge of the learner and the characteristics of the domain. According to Glaser, a useful approach to research is to learn the domain-specific knowledge so that the more general skills are practised during this learning (Glaser, 1984).

Research over the last two decades has directed attention towards domain-specific knowledge. The vagueness of concepts like 'domain', 'subject', is a problem when they serve as a basis for prediction (Ennis, 1990). Therefore it is highly advisable to state the meaning of domain-specificity and domain clearly beforehand (see further in this chapter).

Domain-specificity is the empirically based view that learning or thinking (a) requires prior knowledge, (b) is unlikely to transfer from one domain to another without explicit transfer-inducing instruction, and (c) is unlikely to be learned from general learning or thinking instruction.
According to Ennis (1990) there is complete agreement about the first principle, a majority of educational psychologists agree with the second principle, but psychologists and the research on the third are not in agreement (Ennis, 1989).

Constructing a conceptual model and defining the basic terms

Before we present a conceptual model of prior knowledge, it seems useful to state our own definitions of the basic terms we will use in our research and that will be part of the presented map. The main goal of this section is to arrive at a clear definition/description of the concept 'prior knowledge'. In the further part of this section, this definition will be reworked to obtain an operational approach to prior knowledge ('prior knowledge state') that can be investigated with a specific set of research instruments.

Prior knowledge

Prior knowledge is the whole of a person's actual knowledge:
- that is available before a certain learning task;
- that is structured in schemata;
- that is declarative and procedural;
- that is partly explicit and partly tacit;
- which contains content knowledge and metacognitive knowledge;
- which is dynamic in nature and part of the prior knowledge base, being the total collection of his prior knowledge.

A knowledge interface is helpful in activating prior knowledge by bridging external conditions and the prior knowledge base.

Expertise

Perhaps it is noteworthy to comment on the widely used concept of 'expertise', sometimes used as a synonym of prior knowledge. It is important to state that the expert-novice paradigm is not a true paradigm. In research, beginning students are

largely used as novices, staff or graduates as experts. But who is a novice and when does one become an expert? People who have completed their education in a subject or have a number of years experience in that area are taken to be experts. Graduates, teaching staff, professors, but also students who have pursued a course, and have studied with success are also regarded as experts (Jansweijer, Elshout and Wielinga, 1985). So there can be a great deal of difference between different experts. Furthermore, being an expert is related to a field of study or domain-specific knowledge. An expert in education can be a novice in chemistry. As a consequence, it is perhaps better to talk about experts and nonexperts.

Determining the beginner's level of expertise, however, seems to be much more arbitrary. In the research of Dijkstra et al. (1983) and Larkin (1979), the novice experimental subjects already had a certain amount of expertise in the domain. In other research, such as that of Egan and Schwartz (1979) and Shavelson (1974) beginners were categorized as being 'uninformed', 'having little knowledge' or 'having an almost complete lack of experience'. Beginners are thus defined at different levels and are virtually incommensurable as a homogeneous group. Gradually, cognitive researchers have come to realize that beginners, certainly when defined as those who have acquired some insight into the domain, are a heterogeneous research population. More and more scientists agree on the need to define and to assess levels of expertise more accurately.

Norman (1978) describes an expert as someone who has studied a complex subject for a period of 5000 hours, and during that time has thought about it on a daily basis and has also learned to use the information. The distinction between a novice and an expert mostly resides in the amount of prior knowledge which they have at their disposal. The difference in expertise also influences the procedures people use. Mirande (1981) gave a psychology text to a beginning student and to an expert, and asked them to draw up a schema of the text and a list of specifications

of the concepts used. In studying the text, the student approached it on the basis of: what can I learn from this text? He added new knowledge to his stock of knowledge. The expert asked: how is this subject dealt with? During the reading process he was continually assessing, and comparing the knowledge in the text with her own knowledge. In schematizing the expert included more concepts in her scheme than the student, while her list of specifications had an entirely different content.

Chi, Feltovich and Glaser (1981) carried out three experiments and concluded that experts had a different cognitive structure, comprising what are called schemata. Experts appeared however to be able to name more explicit procedures (if-when relations). As we noted in chapter 2, the structure seems to be one of the most important aspects of one's prior knowledge.

Experts have more prior knowledge than beginners, since the difference between experts and novices can be reduced to differences in declarative and procedural knowledge and the structure of knowledge (see earlier in this chapter). Since the differences can be reduced to different aspects of prior knowledge and since the expert-novice paradigm is not a true paradigm, it implies that in our view it is better to speak of students with more or less expertise, more or less prior knowledge. This implies also that future research should clearly state which level of expertise or prior knowledge their subjects (experts of novices) have reached.

Other basic terms

Declarative knowledge is the accumulation of facts, concepts, relations, structures and principles in a person's memory which can be referred to as 'knowing that'. It comes to the surface in assessment through appreciation, recognition or reproduction.

Procedural knowledge is the total of procedures or methods, referred to as 'knowing how', i.e. referring directly to actions or skills. It comes to the surface in assessment through production or application.

Explicit knowledge is knowledge that is currently employed as an object of cognitive activity and is directly interacting with the world along the interface between the learner and what is being learned. If it is unused at a certain moment, it is immediately accessible.

Tacit knowledge is not directly interacting through the interface and resides at a deeper level. At a particular moment and for a particular task, this knowledge can be elevated (partly or completely) to an accessible level, though not immediately.

We define experiential knowledge as 'regardless of where learning occurs, it is the knowledge acquired through life, work and study, which is not formally attested through any educational or professional certification'.

Apart from the flux between used and unused explicit knowledge and tacit knowledge, the main subdivision within prior knowledge is that between content knowledge and metacognitive knowledge or metaknowledge.

Content knowledge, as a part of one's prior knowledge, is the knowledge of some aspect of one's physical, social, or mental world, and can be formally or informally (experiential) acquired. The formalization or specialization of content knowledge is presented in our framework by the presence of the substructures for domain-specific and subject-oriented knowledge. As a concept becomes central to a specialized field of study, it becomes part of the substructures of domain-specific and subject-oriented knowledge. The relationship between content, domain-specific knowledge and subject-oriented knowledge, therefore, is hierarchical and is based upon their degree of specialization. Moreover, these categories are not to be seen as generic ones.

Domain-specific knowledge (see figure 1) is a more formal subset of content knowledge. It is the total of content knowledge concerning one particular field of study or academic domain, such as law, economics, psychology.

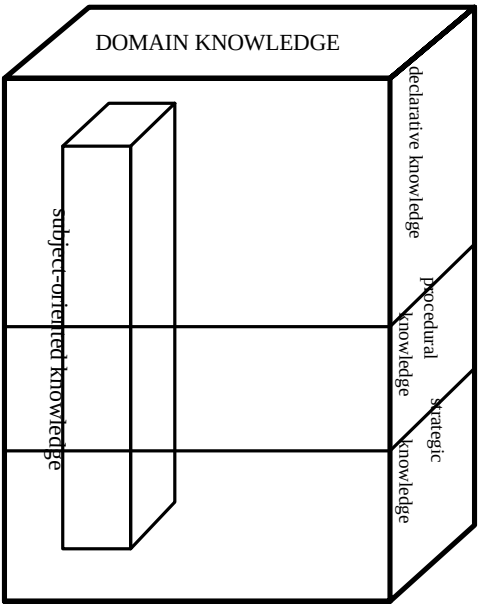

Figure 1: Domain-specific knowledge

Subject-oriented knowledge is a formal part of a certain domain-specific knowledge. It is used as a synonym for course-specific knowledge. It contains a specialized field of study, mostly covered by an academic course.

In our study, we will use that concept of domain to refer to 'economics`. Further, this domain is broken up into financial economics, accountancy, micro-economics, macro-economics, etc., called sub-domains.

Metacognition, as a part of prior knowledge, is the knowledge about one's own cognition and the regulation of that cognition (Flavell, 1987). Regulation means executive planning, monitoring and evaluation of the performance of a task. Figure 2 gives a model of metacognitive knowledge.

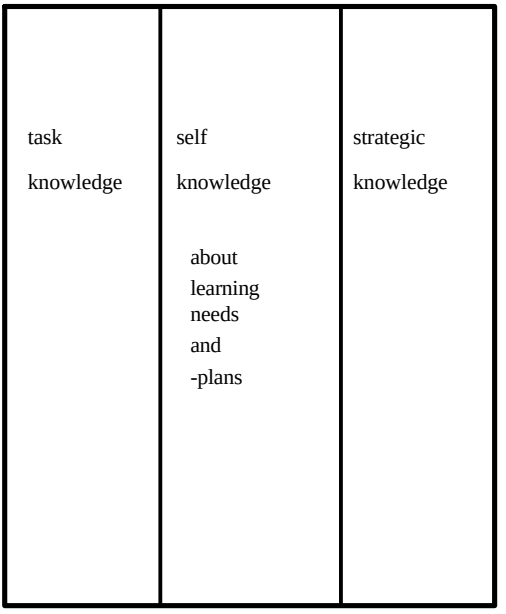

Figure 2: Metacognitive knowledge

In Flavell's use of the term 'metacognition', it "refers to the part of one's acquired world knowledge that has to do with cognitive (or perhaps better, psychological) matters" (1987, p.21). Following Flavell's tripartite subdivision of metacognitive knowledge, we recognize three categories of metacognition related to

person, task, and strategy: self knowledge about learning needs and plans, task knowledge and strategic knowledge.

Self knowledge about learning needs and plans entails individuals' perceptions or understandings of themselves as learners or thinkers. It involves knowledge of what cognitive tasks an individual performs best or worst, how an individual's performance compares to those of others and which learning strategies he uses. Further, it involves the plans that individuals have internalized and their learning needs, influenced by affective understandings about themselves (Alexander, et. al, 1990).

Task knowledge includes knowledge of analyzing the types of cognitive tasks that are encountered. It involves knowledge of the goals individuals establish and the recognition that different types of tasks place different demands on learning or thinking. Task knowledge also involves a kind of cost-benefit analysis in that it allows the learner to balance the importance of completing a task with the amount of cognitive demands of a given task (Pressley and Ghatala, 1988).

Strategic knowledge, in our view, plays a role as a subdivision of content knowledge as well as metacognition.
The first procedure used in the completion of a task is a cognitive strategy, since it relates directly to the fulfilment of the designated task (Flavell (1987) and Garner (1987)). The second procedure is not to complete the task but to evaluate or monitor how well the selected cognitive strategy is working, i.e. a self-checking procedure that is an example of a metacognitive strategy. Therefore, the conceptual framework holds in both areas of content knowledge and metacognitive knowledge a certain amount of strategic knowledge. As the reader will notice, it is not our intention to present a profound elaboration of the literature on metaconition since this will play a minor role in this study.

The knowledge interface is a bridge between prior knowledge and external conditions, which includes the 'instantiation' of knowledge, which is built from the activation and utilization of the individual's prior knowledge, and the 'textbase' (Alexander, et al., 1990). 'Instantiation' (Anderson, Pichert, Goetz, Schallert, Stevens, and Trollip, 1976; Schallert, 1982) occurs from the dynamic interaction of existing knowledge structures built upon prior experiences with available information from on-going experiences. Through instantiation, individuals 'particularize' the abstract representations or understandings that they are forming (Anderson, 1984). Thus, in this interface, the learner builds a meaningful framework from existing knowledge that will facilitate the interchange between what is already known and what is to be understood. This notion of an interface between the internal knowledge structure and external stimuli is important because it emphasizes not only that the system of knowledge within the individual is dynamic but also that this system in continually in flux as a consequence of its interaction with the world external to it.

Conceptual map

In the remainder of this section, we will present our attempt at understanding the given basic knowledge constructs by showing how these terms are related to one another in a conceptual framework (figure 3).
This conceptual map, although illustrating the relations between most of the concepts so far presented, may be somewhat misleading. Since it portrays the conceptual map of knowledge as a snapshot or 'slice-out-of-time` representation, it may be thought to represent a static, non-interactive view of knowledge. Therefore, we feel it necessary to state some basic assumptions about our view of knowledge, assumptions that do not receive direct representation in the visual display.

The conceptual framework focuses on a system that represents an individual learner's prior knowledge. The framework is meant to be a conceptual map and not a processing model of knowledge use.

We hold that forms of knowledge are fluid and dynamic. Not only do these forms vary between individuals but they vary within individuals as well, as a consequence of person, task, or context variables. Further, the forms of knowledge we display can vary in terms of position, order, or size.

It is also a premise that all forms of knowledge are interactive; that is, the presence or activation of one form of knowledge can directly or indirectly influence any other. When confronted with an ill-structured problem about supply and demand, for instance, an adult learner may call upon related content knowledge (e.g., her knowledge of what items department stores mark down for sales) to bolster her weaker, formal knowledge of economics. This interactivity of knowledge has been well illustrated by the work of Voss et al. (1986), Alexander et al., (1989) and others (see Walker, 1987).

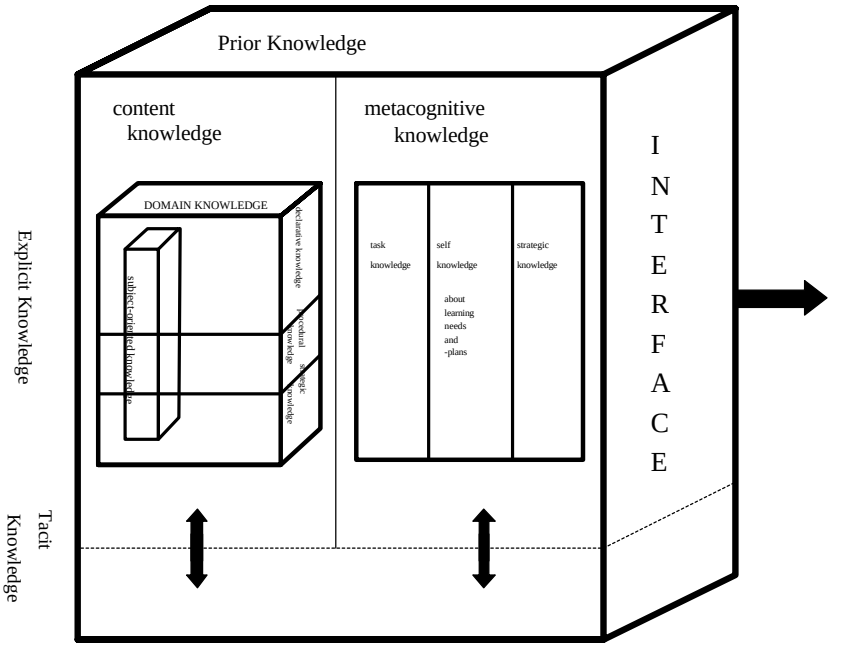

Figure 3: A map of prior knowledge and domain-specific knowledge

Knowledge cannot be dichotomously labelled as tacit or explicit. Therefore we did not picture them. Just as the forms of knowledge are fluid and dynamic, so are

the 'pieces' of knowledge that combine to make up those forms. Tacit and explicit knowledge exist in a state of dynamic interaction for specific tasks. Unused explicit knowledge can become used explicit knowledge. Likewise, knowledge can also function tacitly under different circumstances.

Although we recognize that other conceptual maps can be valid too, we tried to construct ours with a view to making it useful in practice and empirical research. Another model was constructed by Alexander et al. (1990) (see figure 4). This 'propeller' model has some important differences compared to our 'barrel' model. Anderson presents sociocultural knowledge as a different category (which is situated outside our model). Further, the propeller model does not show how for example declarative and procedural knowledge fit into it, although Alexander et al. pay a considerable amount of attention to these concepts in their studies.

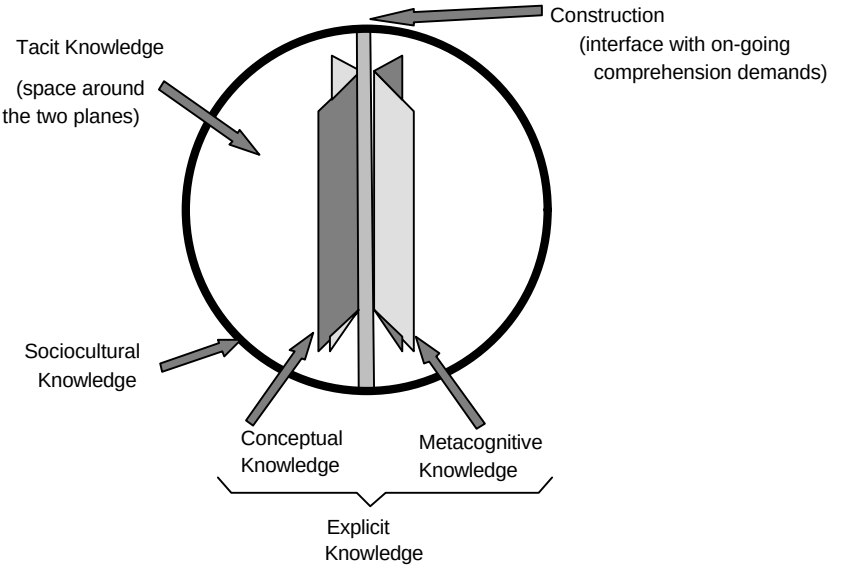

Figure 4: A map of prior knowledge according to Alexander et al. (1990)

A valid indexation of the prior knowledge state concept

Research into students' knowledge states

In this section, we want to clarify our further research approach in terms of choices made to investigate the prior knowledge of students. Therefore, we will stress the importance of a clear delineation of the concepts 'Prior Knowledge State' (PKS), 'Domain-specific Prior Knowledge State'(DS PKS) and our view of learning as a transition between knowledge states. We want to stress that the use of the concept 'knowledge state' is not changing our view on learning and knowledge acquisition as a dynamic process.

One should take account of the current trends in higher education and the progress of educational research. This means that, since prior knowledge is seen as an important variable, it should be noted that the concept 'knowledge state' has become a central issue in educational psychological and technological research. Learning may then be viewed as a successive transition between knowledge states.

By 'knowledge state' we mean a state of prior knowledge. Although knowledge acquisition is a dynamic process, we speak of an individual's knowledge states. This is comparable to a movie which, although it is in constant motion, still exists of many different pictures. Knowledge states are considered as possible epochs in a subject's learning process (Falmagne, 1989). While we defined a knowledge state as a status of a subject encompassing his prior knowledge, Falmagne (1989) defines it more operationally as particular subsets of items. The concept has a natural application in psychometrics (Falmagne, 1989; Degreef, et al., 1986). On the basis of the positions taken in our conceptual map of prior knowledge and taking the ultimate importance of domain-specificity for granted (as we will argue further on), we will direct our research mainly towards content knowledge, i.e. the 'domain-specific prior knowledge state' (see figure 7). This indicates that the concern is with domain-specific knowledge at a particular moment, in this case prior to learning an

assigned learning task. Bransford (1979) speaks of the "current level of previously acquired knowledge and skills".

New educational developments seem even to stress this kind of research into knowledge states.

First, there is the trend towards lifelong learning and adult education. The student population will increase and will become even more heterogeneous; they differ in age, education, work-experience, etc. Taking the prior knowledge state into account could therefore enhance the learning process of the student and lead to better course design and instructional support.

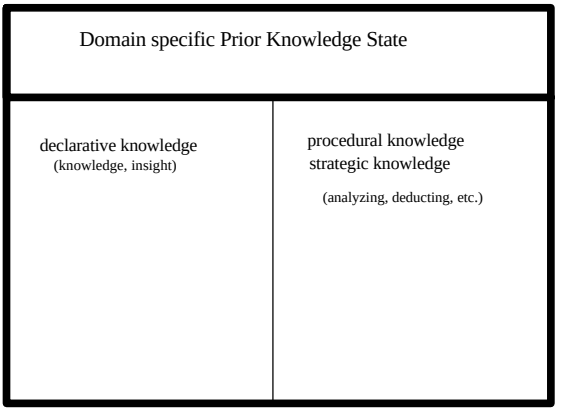

Figure 5: The Domain-Specific Prior Knowledge State

Second, since modular education becomes more integrated, one of the pivotal aspects is the multifunctionality of modules. This means that the more interchangeable the modules are (i.e. the more useful in various faculties, various programmes of various degrees, in different universities and several countries), the more advantageous for institutes and the cheaper they become. In order to achieve this, it is necessary to gain an insight into the prior knowledge state of students and the ability to handle or to use the PKS.

Third, in the development of Knowledge-based Systems (KBS_s), there is a need to know more about the student model, containing especially information about the student's prior knowledge state. KBS_s contain four important components (figure 6):
1. the domain expertise,
2. the pedagogical expertise,
3. the interface,
4. the student model.

The student model, illustrated in figure 8, is used to gain a clear understanding of the student's knowledge state and to make hypotheses about his or her conceptions and reasoning strategies employed to achieve the current knowledge state. In the past, too little attention has been paid to the development of the student model.

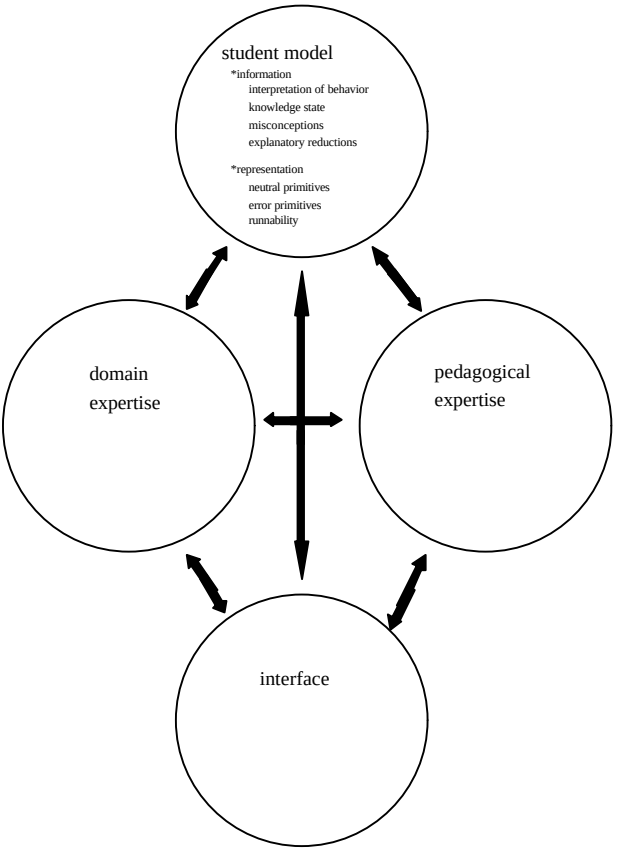

Figure 6: Components of knowledge based systems

When learning is viewed as successive transition between knowledge states, the purpose of instruction is accordingly to facilitate the student's transversal of the space between knowledge states.

This definition involves two basic types of activity:
- attempts to determine the student's knowledge state; and
- attempts to cause or support a transition to the next state.

For this reason, the research project was divided in two parts. The first part, directed towards investigating possible ways of determining the student's prior knowledge state, its role in the learning process and the construction of a set of knowledge state tests and knowledge profiles (as reported in the present study). The second part of the project is directed towards the development of Knowledge Acquisition Support System prototypes (one of the starting points of the actual KASS project) (Koper, 1989, 1990).

Validation and indexation

A valid indexation of the prior knowledge state could lead us further along our way to effect our aims. The pivotal questions in this part of the study are: which variables indicate the existence of prior knowledge on the part of students? Which variables represent the 'prior knowledge state' in a valid way?

Segers (1977) writes that the concept of validity relates to the question of whether the theoretical characteristic at issue can be ascertained by means of the phenomena selected. The validity principle means that research data must be such that it is legitimate to move from the level of empirical variables to that of

theoretical concepts. Carminus and Zeller (1979) formulate this simply by saying that "an indicator of some abstract concept is valid to the extent that it measures what it purports to measure."

Segers (1977) introduces in our view a clear and useful distinction between indexation and operationalizing within the process of translation from the theoretical to the empirical. The significance of these terms and their interdependence is made clear in figure 7.

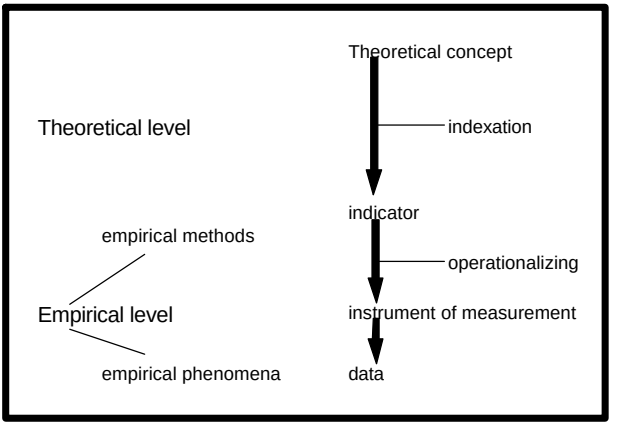

Figure 7: Indexation and operationalizing (Segers, 1977)

In the present study, we shall use this distinction as introduced by Segers.

He regards indexation as the first step in the 'translation' of the abstract concept and operationalizing as a second step, in particular, the translation of the empirical phenomena into an instrument for measurement in the narrow sense (for example questions, a thermometer, a test...). A concept can often distinguish more than one dimension. Indexation is only valid when all properties are represented in the indicators, which are distinguished in the definition of the concept as a dimension. In our case, Segers (1977) advises to track the dimensions from research into the literature. The validity of the dimensions should be confirmed by experts in the field.

When applied to our research, it becomes clear that first we should turn our attention to the indexation of the concept. The different properties and the dimensions are examined in this exercise. In any given situation, various properties of a concept-as-meant may often be active at the same time. For that reason most constructs are reduced to their various properties as the first step in indexation. The concept-as-meant, i.e. the prior knowledge state, is divided into separate properties which can be distinguished from one another. These properties are ranged along dimensions. The distinguishing of these properties is also a first step on the way to operationalizing.

In this case it is a question of content or face validity. Segers (1977) claims that "the relationship between the construct-as-meant (theoretical characteristic) and construct-as-measured (empirical variable) is supported by arguments which indicates that the 'content' of the indicator accords with the 'content' of the theoretical characteristic". Face-validity is the assessment of indicators on their 'external appearance' as a representative of a theoretical concept or dimension. The consensus that can arise within a scientific forum about the validity of an indexation raises face-validity, from a methodological point of view, above pure

subjectivity. The judgement of experts (fellow-researchers, content experts) determines content validity. Content validity can however only be approached when the researcher pays attention in the first instance to the quality of instrumental design. Segers (1977) distinguishes theoretically four essential stages in the design of a content valid instrument:

a) theoretical concern with the elucidation of the significance of the content of the construct involved;
b) the recognition and specification of the theoretical dimensions of the construct;
c) the careful choice of indicators for each of the dimensions distinguished;
d) the assessment of the manner in which the different indicators have to be joined to one valued determinant.

In this project we shall investigate whether the content of the dimensions accords with the theoretical construct of the 'prior knowledge state'. This method of content validation which accords with the various stages distinguished by Segers (1977), includes a theoretical discussion of the research and also a theoretical consideration and elucidation of the theoretical construct. This is performed by means of a study of the literature and a study of the PKS within a scholarly forum, i.e. among various experts in the area of cognitive psychology and artificial intelligence. This inter-subjective assessment by experts will in the first instance be directed at the validation of the significance of the concept that is to be measured and of its potential properties. The relationship with the assessment instruments will be discussed later on.

For a extended description and discussion concerning validity, indexation and methods of validation, we refer to Dochy (1988).

3.3 Indexation by means of research into the literature and by expert judgements

In the first instance, our study of the literature refers to the use of prior knowledge in higher education, in research and in theories on the facilitating influence of prior knowledge (chapter 2). The second part of research into the literature is directed at work on the indexation of the concept of 'Prior Knowledge State' (PKS). In addition to the above, a questionnaire was compiled comprising general questions on the significance of the PKS construct i.e. domain-specific prior knowledge state and the methods of establishing it. Potential respondents to this questionnaire were all experts in the areas of cognitive and instructional psychology or artificial intelligence. In order to select from this group of experts those who were active in research on prior knowledge, an inventory was made of the Dutch- and Flemish-speaking experts during the study of the literature. A questionnaire was sent to twenty-seven experts. From those, although some replied that they felt honoured but did not consider themselves experts in this field, seventeen answered all the questions.

As stated in the beginning of this chapter, real definitions come more often from the experts than from the literature. The descriptions that proceed from know-how already acquired, i.e. prior knowledge that has a clear influence on performance provides little that helps to make the construct of prior knowledge state usable and they are not included here. For example, the statement that the prior knowledge state is that part of a person's knowledge that influences the learning, processing,

reproducing and using new material in a given situation. Such definitions do not say what prior knowledge is, but what has been established by means of research. A second example is the following quote: "In the natural sciences and mathematics it can be stated that the ability to solve a type of problem gives an indication that the student possesses the prior knowledge necessary to learn a particular part of the subject. In this 'reversed' situation the performance is supplied by solving problems or carrying out work which is unjustly regarded as the proof of the influence of prior knowledge.

As stated before, the definitions in literature are so vague that on the basis of these alone, it would hardly be possible to make an indexation. The questionnaires returned by experts resulted in more real and concrete definitions. An overview of these can be found in Dochy (1988).

After a content analysis of all responses, it appears that the experts highlight a number of PKS properties. Emphasis is on five properties: the presence of knowledge, insight and skills, its structured nature, its dynamic nature (ongoing updating), the availability of information required; knowledge and skills, being present before the implementation of learning activity. Experts mostly refer to domain-specific knowledge or knowledge about subjects. Moreover there is also in the literature a tendency towards research into the domain-specific prior knowledge state. It should be noted that in our view the dynamic nature must be interpreted as constructive.

In accordance with the literature and the definitions given by experts, in our research we will try to investigate mainly the domain-specific prior knowledge of students. Metacognitive prior knowledge was investigated by Vermunt (1987) and received considerable attention in the research on Knowledge Acquisition Support Systems by Koper (1989, 1990). We will explain our reasons for making this choice for domain-specific prior knowledge more fully later (part 4 of this chapter).

Hereafter, when the PKS is referred to, it may generally taken to mean domain-specific prior knowledge state.

As a results of the mentioned analysis, the prior knowledge state can be described as the knowledge state comprising existing declarative knowledge and procedural knowledge which meets the following conditions:
- that it is present before the implementation of a particular learning task
- that it is available or able to be recalled or reconstructed
- that it is relevant for the achievement of the objectives of the learning task
- that it is organized in structured schemata
- that it is to a degree transferable or applicable to other learning tasks, within and possibly outside the domain
- that it is dynamic in nature.

The prior knowledge state can be schematically presented as a knowledge state that exists at a particular moment (before the implementation of a learning activity), and that is available for the achievement of particular learning objectives (figure 8). Knowledge which has to be explained is reconstructed in transferable schemata.

In the literature and among experts there is general consensus on a number of properties which shed light on the PKS. These are part of the proposed indexation.

From the above analyses of literature and expert judgements (for detailed information, see Dochy, 1988), eight properties can, in principle, be derived for an indexation of the PKS:

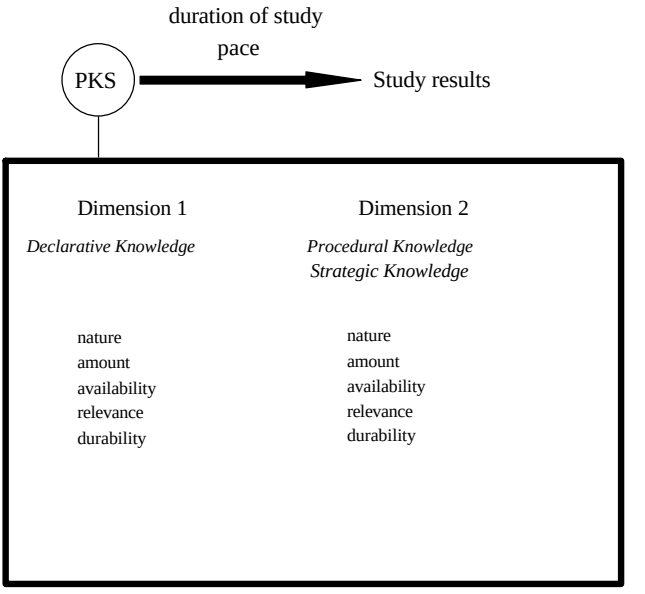

Figure 8: Indexation of the prior knowledge state as established at a particular moment before the implementation of a learning activity

1 the nature and amount of prior knowledge;
2 the availability of prior knowledge;
3 the structuring of the cognitive structure;

4 the relevance of information in respect to the learning objectives;
Next to these, studies in literature show two other properties, being:
5 the pace or duration of the learning process;
6 durability of what is retained;
and also two variables from a somewhat different order, related to what we called experiential knowledge:
7 previous education;
8 work experience (and age).

Operationalizing the different properties of the prior knowledge state and asurement instruments

When investigating the role of prior knowledge state in the learning process, the next task after the indexation of the concept is the operationalizing into useful assessment instruments (Segers, 1977).

Coming to the problem of how to assess the prior knowledge state of students, it seems logical to try first the easiest (i.e. the least time-consuming and cheapest) method.

Earlier research showed that prior knowledge has a substantial influence on study results. In view of the above, measuring prior knowledge by means of a single available indicator is the first possibility that should be considered (chapter 4). We might then consider measurement by means of a combination of several available indicators (Dochy et al., 1990). For example, variables as sex, age, work experience, previous education and others could correlate with or could be significant predictors of the study results of students. If this were the case, it would be worthwhile looking more closely at a variable that correlates strongly with prior knowledge. The validity of these possibilities will be tested in the ex post facto research and experiments described later.

Following that, different prior knowledge state tests will be developed, since indicators will give us few information on the properties of the prior knowledge state and thus will not be very helpful in enhancing educational practice and the student's learning. These different tests will be related to the different properties of the student's PKS (prior knowledge state) (figure 16).

From the information received from experts in the field, as described earlier, and from research into literature, we tried to operationalize the different properties in

order to connect them to assessment instruments. With regard to the various properties of the PKS indexation, we found several tests in literature that offered possibilities for their measurement. Moreover, we tried to go beyond 'baseball type' prior knowledge state tests.

For this reason we sent questionnaires to the economists at the universities of Heerlen and Maastricht and to different experts in educational testing at Dutch universities. The aims of this were to investigate the need for different sorts of prior knowledge state tests (PKST), to get information about PKST that had been used in the past and to find procedures for developing new kinds of PKST. The questions were directly related to these aims. The economists did find two sorts of tests of crucial importance in trying to establish the student's prior knowledge state.
A subject-oriented PKST, defined as a test measuring the knowledge that is provided in a specific course, and a mathematics PKST, being a test measuring the mathematics knowledge required for following the course, i.e. at the end of secondary education level. Economists and educationalists agreed on the necessity of using a domain-specific PKST, being a test providing information on the student's knowledge concerning the whole domain of economics, divided into different subdomains. Further, educationalists stressed the importance of using cognitive structure tests and portfolio assessment.
Finally, some of the respondents suggested taking account of the optimal requisite knowledge (OR). This optimal requisite PKST was intended to assess the content knowledge that is required to study the course in optimal conditions. Of course, it was meant to cover the content knowledge that is not available in the specific course (and which is included in the subject-oriented PKST).

Some of these tests are used in the field of educational testing, although some of them are not well known and mostly they are not used as instruments for the assessment of the prior knowledge state. As noted in our review of research, short

subject-oriented and mathematics PKST are often used to measure the prior knowledge state. At the University of Limburg, the PES (Project for Evaluation of Study results) and Imbos (1989) have been experimenting with domain-specific tests to assess the prior knowledge state and the development of that knowledge. In the literature evidence was found that a method called 'error analysis` can provide useful information on the availability of the prior knowledge and to some extent on the nature of prior knowledge in terms of the possession of incorrect prior knowledge or misconceptions (Alexander et al., 1989; chapter 2).

In total, we found seven assessment instruments which offer the possibility of getting a picture of the student's prior knowledge state:
1 a subject-oriented prior knowledge state test;
2 a mathematics PKST;
3 an optimal requisite PKST;
4 a domain-specific PKST;
5 a cognitive structure test;
6 an error analysis procedure.

The construction and content of the tests we will use in our empirical studies will be described later (chapter 7). At this point, we will explain the connection between the different properties of the PKS we want to measure and the assessment instruments. This explanation will be based mainly on the literature (Alexander et al., 1988; Chiesi et al., 1979; Ennis, 1990; Freebody et al., 1983; Glaser, 1984; Hare, 1982; Langer, 1980, 1981; Matthews, 1982; Prawat, 1989) and partly on information obtained through personal communication with scientists (Wijnen, De Corte, de Wolf, Segers, Kroksmark, Drottz, Sjöberg; 1989 -1991).

Figure 9 gives an overview of these theoretical relations. We will describe them shortly.

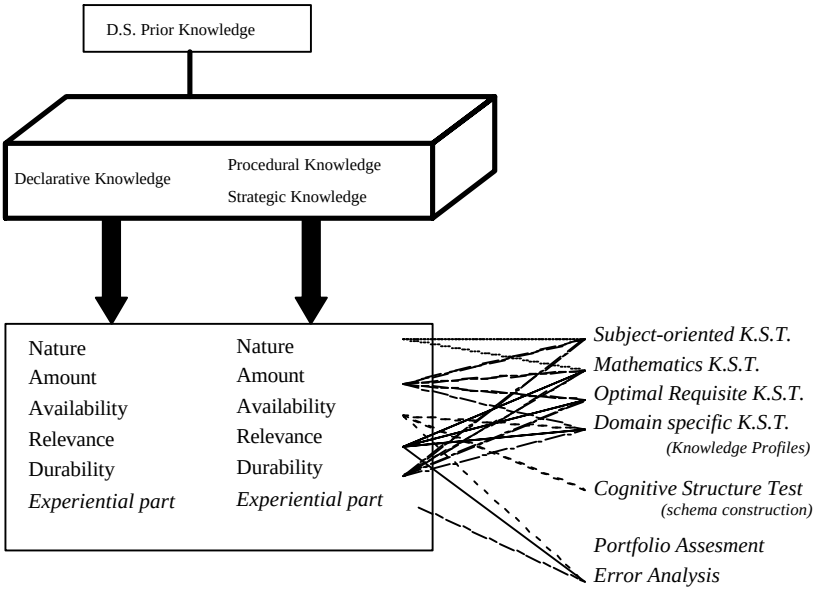

Figure 9: The relationship between different aspects of the domain-specific prior knowledge state and knowledge state tests

1. The nature of the prior knowledge state can be measured by the subject-oriented PKST, the maths PKST and the domain-specific PKST. They refer to different parts of the PKS or PKS components. While the subject-oriented PKST and the math PKST provide limited information on the relation of the PKS with the course content or mathematics, the domain-specific PKST gives an overview of the PKS within the whole domain (e.g. economics) and within the different subdomains (e.g. micro-economics, macro-economics, accountancy, etc.). In chapter 10, possibilities to detect the nature of the PKS beyond the subject-matter level will be tackled. To make this overview more clear, easier to interpret and available for students, we develop 'knowledge state profiles` based on the DS PKST (for examples see chapter 10).

2. The amount of prior knowledge can be measured by means of all PKST, which will each provide information on the amount of a certain component of the prior knowledge state: course specific, maths, optimal requisite and the total of domain-specific prior knowledge.

3. The availability of knowledge, being the ability to draw on or utilize resources, is closely related with accessibility. As viewed in most research, access and availability are largely a function of two important factors: organization and awareness. Connections between key concepts and procedures provide the glue that holds the cognitive structure together (see chapter 2). The adequacy of this structure in turn determines the accessibility or availability of resources at a later time. By means of a cognitive structure test information is provided on the availability and accessibility of prior knowledge. In addition, the domain-specific PKST gives some indications on the structure and availability of knowledge within a domain.

4. The relevance of the prior knowledge state can mainly be tested by two instruments. First, the optimal requisite PKST measures the required and relevant knowledge that is necessary to follow the course. Second, error analysis makes by means of patterns of errors a map of the irrelevant knowledge that was used by the student (see Dochy and De Corte, in press). Because of the vagueness, difficulties for interpretation and time consuming work related to the latter method, it was not used in this study.

5. According to the above-mentioned literature, durability of knowledge can be assessed by means of all PKSTs using a repeated testing procedure.

6. The experiential knowledge can be assessed by means of portfolio assessment and the assessment centre method as advocated by Wagemans and Dochy (1989, 1991) and Dochy, de Wolf and Wijnen (1991).

4 The scope of our study: the choice for domain-specific prior knowledge

From our investigation with experts, we concluded that they mostly focus on domain-specific (DS) prior knowledge state.
By means of an updated literature study (up to 1991), we looked for evidence that would support focusing our studies on domain-specificity. It is obvious that the experts in the field of educational and cognitive sciences are influenced by

scientific articles and writings, but our worry was to find out whether there was a new fashion or rather a justified trend.

In this paragraph we will argue our design and the choices made for our empirical studies on the basis of recent contributions to a theory of prior knowledge.

Contributions to a theory of expertise

Cognitive research assumes that what guides actions are the schemata or cognitive structures that reside in individual minds. Some studies of expertise defined these structures that are used for various academic and practical tasks, with the underlying assumption that novices could be taught the knowledge structures that experts use, and thus become experts themselves.
More recent cognitive studies contributing to a theory of expertise begin by defining expertise from the perspective of prior knowledge that is used in practice, leading to the speculation that the acquisition and the use of expertise is more tightly bound to particular contexts than was assumed earlier.

Looking at our model of prior knowledge, it is clear that using prior knowledge involves the two different parts, i.e. the content-directed part and the metacognitive part. The literature on skilled problem solving and expertise research has led to the identification of three categories that should be mastered with a view to approaching a task appropriately and with a fair chance of being successful (De Corte, 1990b):

1. flexible application of a well-organized domain-specific knowledge base;
2. heuristic methods, i.e. systematic search strategies for problem analysis and transformation;
3. metacognitive skills.

To limit the scope of our further research however, we will focus in the rest of this study only on domain-specific knowledge. In the first studies we will be concerned with De Corte's first category. When necessary for the implementation of research results in practice, we will scrutinize heuristic methods.

Domain-specific prior knowledge

There is a considerable amount of evidence that the domain-specific prior knowledge is the form of prior knowledge that most affects the learning process and results. The importance of domain-specific knowledge has been well demonstrated for students of different ages (Glaser, 1987; De Corte, 1990b). It was even found that domain-specific prior knowledge already strongly affects the solution processes of young children on arithmetic word problems (De Corte and Verschaffel, 1987). Above all, the DS prior knowledge should not be mixed up with the overall general ability called intelligence. In the fifties, one still believed that more intelligent people could learn things that less intelligent could not. A careful inspection of empirical findings makes this doubtful for some reasons. First, the correlation between intelligence and achievement is highly variable. Statistical meta-analyses have yielded overall coefficients that range between .34 and .51 (Fraser et al., 1987). Second, if one partials out the influence of prior knowledge, the correlation between intelligence and study result is drastically reduced to values ranging between .0 and .30 (Weinert, 1989).

Further, the results from studies on metacognition show remarkable parallels with the results from intelligence studies looking at predictors of learning outcomes (Weinert, 1989). According to his statistical analysis of available data, Schneider (1985) found a significant correlation of .41 between metacognition and performance. But again, Weinert (1989) replicated the study, partialling out the effect of prior knowledge, and concluded that the former conclusion did not hold any longer. The correlations between metacognition and performance diminished just as much as in the intelligence case i.e. a decrease between .34 and .21. (r was between .07 and .20). Even on the basis of other studies Weinert (1989) concluded that "contrary to expectations, past research has shown that motivational variables and instructional characteristics make very little contribution to the prediction of school performance". This is in agreement with Schmidt's opinion (1987).

In our view, Weinert (1989) concluded properly that the basic postulation of the new approach is: domain-specific prior knowledge (rather than the intellectual ability or the metacognitive competence) determines the process and outcome of learning and reasoning. Earlier, we have advocated acceptance of this opinion, but one should remember that in our view, the lack of evidence regarding the effects of intelligence and metacognition could result from the nature of the assessment instruments.

Convincing evidence for the prior knowledge effect is provided by the earlier cited work of Weeda (1982) and certainly the study of Bloom (1976) and the synthesis of meta-analyses by Fraser et al. (1987). This reveals a fairly high mean coefficient of .75 for the factor of domain-specific knowledge in predicting achievement.

Further investigating the role of domain-specific prior knowledge, Weinert (1989) did find that prior knowledge had a strong impact on performance. The correlations between prior knowledge and performance remained significant even

with intelligence scores partialed out. Also he concluded that domain-specific knowledge can compensate for low intellectual ability, but a high intellectual ability cannot compensate for a low prior knowledge. This pattern of results coincides with the study by Walker (1987), using baseball texts. Moreover, in this study, Weinert recognized that metacognition did play a certain role: a high level of metaknowledge was related to a better performance, independent of soccer expertise.

Out of these studies it emerges that the combination of domain-specific knowledge and general metaknowledge leads to especially good performance. Körkel (1987) analyzed the relations between age, intelligence, metacognition, prior knowledge and performance through a correlational pattern. Figure 10 gives the LISREL model representing the parameter estimations for the structural relationships.

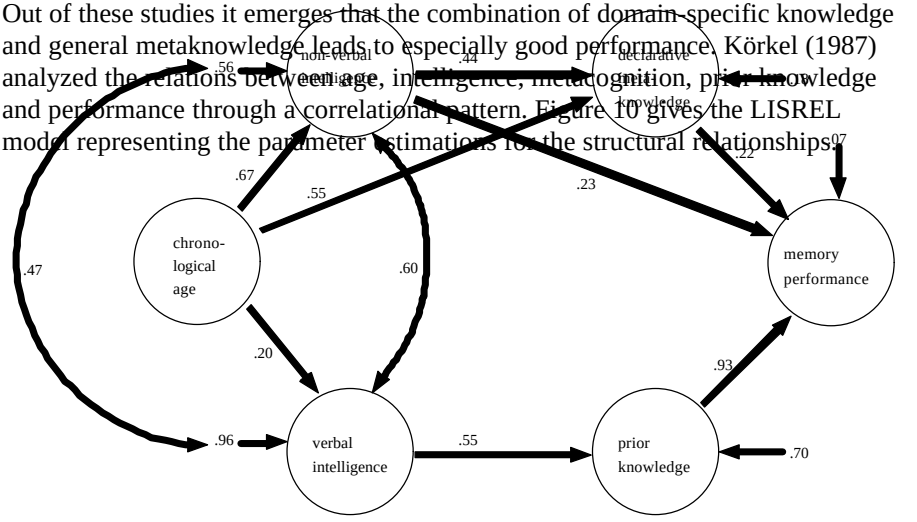

Figure 10: LISREL model of structural relationships (after Körkel, 1987)

The most important finding again is the superior explanatory power of content-specific knowledge, i.e. the most significant path in the model. In a replica of the soccer study, Weinert (1989) found that domain-specific knowledge is a decisive prerequisite for good mathematics achievement.
Overall, he concluded that "the past is in fact the best predictor for the future. Differences in the knowledge base are the main source of intra- and interindividual differences in cognitive achievement, irrespective of chronological age or the specific domain of knowledge".

5 Conclusion

Without some consistency in the usage of the terminology of prior knowledge and without explicit and precise definitions of these concepts, researchers and readers run the risk of misconceiving the studies and misjudging the results. Therefore in this chapter, we reviewed main issues related to that terminology and we defined the basic terms.

For a good understanding of the proceeding chapters, it is worthwhile to recapitulate the following definitions. 'Prior knowledge state' is the knowledge state comprising existing declarative knowledge and procedural knowledge which is present before the implementation of a particular learning task, is available or able to be recalled, is relevant for the achievement of the objectives of the learning task, is organized in structured schemata, is to a degree transferable or applicable to other learning tasks, within and possibly outside the domain and which is dynamic in nature. Domain-specific knowledge is a more formal subset of content knowledge. It is the total of content knowledge concerning one particular field of study or academic domain, in our case economics (see figure 1). Subject-oriented knowledge is a formal part of a certain domain-specific knowledge. It is used as a synonym for course-specific knowledge as covered by an academic course.

The research described resulted in the proposed conceptual map (figure 3). We have presented an argument for the operationalizing of the properties selected into usable assessment instruments, from which some will be used in our empirical studies. Finally, our choice for stressing the domain-specific prior knowledge has been argued.

"Show me what you know and I will tell you whether you have selected appropriate learning objectives".