Chapter 2
Effects of prior knowledge on study results and learning processes: Theoretical approaches and empirical evidence

1 Introduction

In this chapter we will look for more evidence concerning the effect of prior knowledge on learning outcomes and processes in order to make a clear link between these findings and the choices of the previous chapter. In the first paragraph, after some overall evidence, a summary of representative and well-known studies illustrating the impact of prior knowledge on study results i.e. the contribution to post-test variance is given. Next we will give an overview of different effects of prior knowledge on learning processes. In part three we will review theories and research that give an explanation, mainly for the facilitative effect of prior knowledge on learning and we will argue how these fit into the chosen information-processing (IP) model.

2 The effect of prior knowledge on learning outcomes

The work of Ausubel was certainly not the first to direct attention to the importance of prior knowledge. However, his work has led to renewed psychological interest in learning in institutionalized educational contexts. Ausubel highlights an important moment in the development of a sub-field within a branch of psychology that is generally called educational psychology (Lodewijks, 1981). In his basic text 'Educational Psychology: a cognitive view' he writes unhesitatingly about the crucial role of prior knowledge in learning: "If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly." (Ausubel, 1968). This involves a tripartite assumption (Lodewijks, 1981) i.e.:

- prior knowledge is a very important variable in educational psychology;
- the degree (content and degree of organization) of prior knowledge of a student must be familiar or measurable for the achievement of optimal learning;
- a learning situation is optimal to the degree to which it is in accord with the level of prior knowledge.

Recent literature in educational psychology however, indicates that there has been only limited advance on this position. There has been little research into methods of establishing students' levels of prior knowledge (Letteri, et al., 1982). Nevertheless, in recent research into cognitive processing activities one can detect an increasing interest in the role that student's prior knowledge plays in acquiring new information. Anderson and Pichert (1978) write: "The knowledge a person possesses has a potential influence on what he or she will learn and remember...". The reader will note correctly that the basic conceptualisations in this context come

from the late seventies and early eighties. Also the conclusion of Beukhof is worthy of note: "Comprehension is best represented as an interaction of content in text and the reader's prior knowledge". This increasing interest has lead to several noteworthy results. One of the foremost results of recent research in cognitive psychology is the consciousness that 'old' knowledge plays an important role in the acquisition of 'new' knowledge. Secondly, it seems that the amount of knowledge has a substantial impact on the learning process (Chi, Glaser and Rees, 1982). Knowledge that the learner already has about a particular subject appears to exercise a considerable influence on the manner in which and the degree to which new information is understood, stored and can be used. Furthermore it is accepted that both the acquisition of knowledge and the learning of skills is dependent upon entry behaviour. (Neisser, 1976; Dochy and van Luyk, 1987).

Also in psychological models of educational performance, prior knowledge mostly plays a major role. This is the case in the Carroll model, the Cooley and Leinhart model, the Harnischfeger and Wiley model, the Bennett model and the Glaser model (for an overview, see Haertel et al., 1983).

The fact that prior knowledge has been demonstrated to be a potentially important educational variable in the sense of contribution to post-test variance was shown in several investigations (for an overview, see Bloom (1976) and Dochy (1988)). Weeda (1982) found that knowledge measured prior to a course, explained, on average, no less than 50% of the variance in the post-test scores. Comparable results were reported by Bloom (1976) who found correlations between 0.50 and 0.90 between pre-test and post-test scores. From these correlations, Bloom deduced the amount of explained variance. Lodewijks (1981) found a correlation of 0.60 between the assessment the students made of their prior knowledge and their performance in post-tests. The results of the research into the influence of variables on study results demonstrate that prior knowledge explains between 30 and 60 per cent of the variance in study results. On the basis of a selected review of studies, Schmidt (1987) concluded that more attention should be payed to prior knowledge in the development of more effective instruction. Figure 1 gives an overview of the relative influence of the different factors in learning.

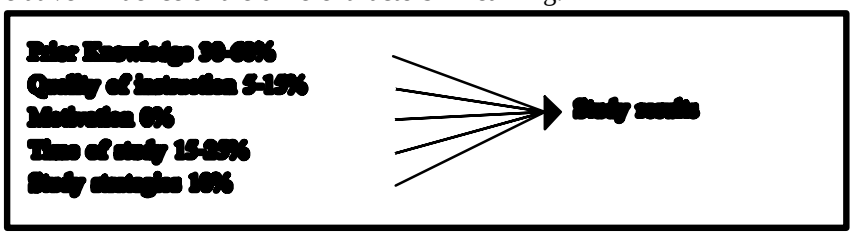

Figure 1: An overview of the educational variables and their relative influence on study performance (after Schmidt, 1987)

The data in figure 1 should, of course, be interpreted with caution. The figure is a schematic repesentation of relations which exist in reality. Much of the research in

this field shows considerable more complex relations than are given in the figure. One should take into account that the main purpose of the figure is to show the direct impact of certain variables on study results. Motivation for example has hardly any direct influence, but several theories postulate a causal influence of motivation on study time (Parkerson, et al., 1984). The variable time allocated to self-study then has a substantial direct influence on study results.
It should be noted that studies using multiple regression techniques run into problems of interpretation when using broad constructs such as 'prior attainment', since such variables can 'contain' aspects of for example motivation or ability.

Parkerson et al. (1984), in an attempt to explore causal models of educational achievement, came substantially to a similar 'simple productivity model'. However, this simple model seemed inadequate because of a general lack of fit and many nonsignificant structure coefficients. Nevertheless, their 'complex model' (figure 2), with a good overall fit and a multitude of significant structural coefficients, stressed once more the importance of prior knowledge. Here also, caution is needed to interpret correlation within causal path models, such as the negative correlation (figure 2), possibly caused by students critical of instruction.

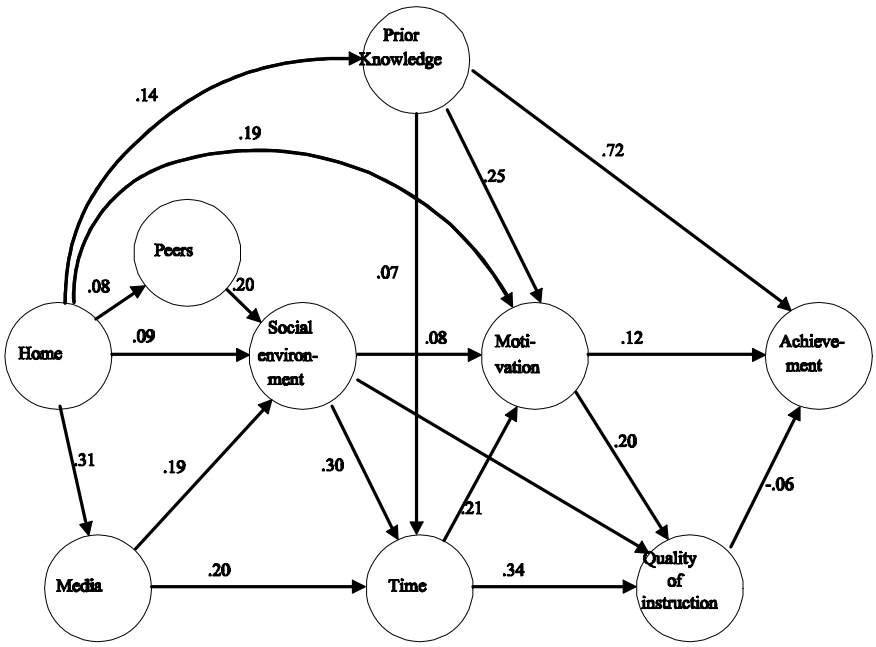

Figure 2: Complex causal model of educational achievement (free after Parkerson et. al., 1984)

Effects of prior knowledge on the learning process

3.1 Direct and indirect effects

In research on learning and instruction, investigations have also been looking towards the effects of prior knowledge on the learning process. It will be clear that different effects on the learning process will have an impact on the results. These effects on learning, which may be positive or negative (support or hinderance), will be reviewed in the next paragraph. They can be classified in three categories. First, there is an overall effect of facilitation of learning leading to better study results. Second, there are inherent qualities influencing the facilitating effect (sometimes described as independent effects). Third, there are the effects of interaction between the first two stated types of effect.

The facilitating effect of prior knowledge is generally recognized by educational researchers as being the most important positive effect on learning. In part 4 of this chapter we will state different theories that give an explanation of this finding. Nevertheless, we should not forget that not all facilitating effects are the 'direct' results of prior knowledge. For the purpose of this review, we can make a distinction between:

a. a direct effect of prior knowledge facilitating the learning process and leading to better study results;
b. an indirect effect of prior knowledge, optimizing the clarity of study materials; and
c. an indirect effect of prior knowledge, optimizing the use of instructional and learning time.

The different relationships can be illustrated when causal modelling is used to analyze the overall relational pattern of variables. Figure 10 (chapter 3), resulting from an analysis using LVPLS (Latent Variables path analysis with Partial Least Squares estimation) as a causal modelling technique, shows according to Weinert et al. (1989) that prior knowledge not only affects subsequent achievement directly, but also indirectly as a result of intermediate instruction parameters. In our view, the causal model of Parkerson et al. (1984) as presented in figure 2, shows this more clearly.

Further, it should be noted as important that we, as other authors reporting on the facilitative effect of prior knowledge, make an implicit assumption concerning the state of that knowledge. This assumption is that prior knowledge has certain characteristics (i.e. qualities), namely it is reasonable complete and correct, of reasonable amount, of good accessibility and availability, and well structured.
Consequently, if we consider the prior knowledge state as the independent variable and study results as a dependent variable, these qualities must be seen as intervening variables, causing interference.

3.2 Inherent qualities of prior knowledge influencing the facilitating effect

The generally accepted facilitating effect of prior knowledge emerges from the

implicit expectation that the subject has a high quality knowledge base (correct, complete, high availability and accessibility). Moreover, most research applies this assumption by saying that the more prior knowledge, the better are the study results. In our view, however, the amount and the relevance of prior knowledge are two sides of a butcher's knife. This means that some research results must be interpreted with caution since not all prior knowledge is relevant.

We distinguish six inherent qualities of prior knowledge (for a literature review, see Dochy, 1988).
- Incompleteness: parts of prior knowledge are correct but not complete (De Klerk, 1987). For example, a person knows that the earth is turning around the sun and consequently thinks that the day and night is a result of this, lacks the knowledge that the earth is rotating on its axis.
- Misconceptions: conceptions which are wrong, such as being convinced that the sun orbits around the earth. In the phenomenographic approach, researchers speak often of 'naive conceptions' (Duit and Säljö, 1988).
- Availability: prior knowledge can be ready for use or not, for example if it is not activated.
- Accessibility: prior knowledge that is not available immediately can be entered (accessible) for example when it is organized in the correct schema.
- Amount and structure: a person can have a lot of prior knowledge on a subject or not and it can be highly structured or not.

If these qualities differ from the assumed perception, the facilitating effect of prior knowledge (direct or indirect) will increase or decrease (see figure 3).

It must be noted that most of these inherent qualities are often reviewed in literature as autonomous effects of prior knowledge. For a description of the influence of these qualities, we refer to Dochy and De Corte (in press).

3.3 Interaction effects between the facilitating effect and the inherent qualities

Interaction effects result from the interaction between the inherent qualities (or IQE's) and the main facilitating effect (figure 3).

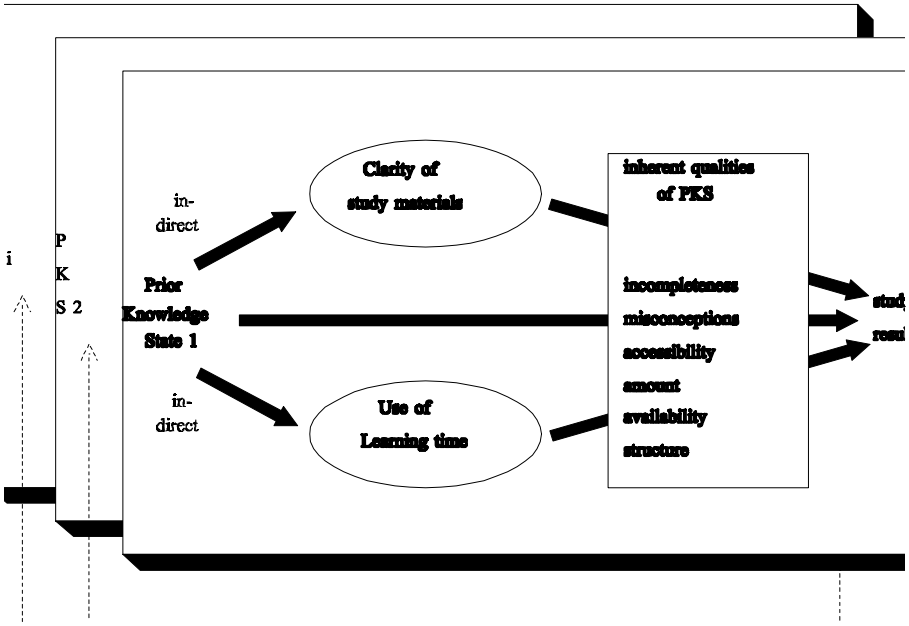

Figure 3: Interaction effects involving inherent qualities and the facilitating effect

It is found in most studies that subjects form the high knowledge group (with high amount of relevant domain-specific knowledge) have several advantages over those with low knowledge (Alexander, Garner, Gillingham and Kulikowich, 1990).

Although the overall effect remains significant and dominant, the high knowledge students do not suffer so much from the incomplete conception and misconception effects. Also, the seductive detail effect remains, but this is in favour of high knowledge individuals (when details are truly seductive, that is, when they do not support structurally important ideas (Wade and Adams, 1989)).

These examples of interactions do suggest that there is a certain hierarchy in prior knowledge effects, in which effects with a higher classification overrule those with a lower classification. It seems obvious that the facilitating effect is at the top of this hierarchy, irrespective of whether we talk about a hierarchy based on the average occurrence or the average impact. There is, however, no evidence in past research to argue for a certain ranking in the lower levels. In the present study we will mainly focus on the facilitating effect. More detailed information concerning the interaction effects can be found in Dochy and De Corte (in press).

4 Explaining the effect of prior knowledge and embedding theoretical approaches and research into the IP model

In our view, a common theoretical framework of explanatory theories and concepts would be beneficial to educational psychological research into previously acquired knowledge. Further research in this field should concern itself with this theoretical framework and build upon earlier results.

This paragraph gives an overview of the research into the effect of prior knowledge on learning and the theories flowing from it which offer an explanation mainly for the facilitating effect of prior knowledge. Further, we try to clarify the relation between the theoretical approaches and research findings and the information-processing (IP) model.

The general facilitating effect of prior knowledge has been known to educational psychologists for some time, but until recently (i.e. the mid-seventies) there was little or no research into the use and influence of prior knowledge. On the contrary: attempts were made to exclude the effect of prior knowledge as far as possible, for example by using nonsense syllables in experimental research situations. This was done in the hope - that has since been demonstrated as futile - that fundamental patterns in the learning process could thus be studied in isolation (Van Dam, 1979). When prior knowledge eventually did surface and survived within this artificial and restricted framework ,it was in a transfer experiment which investigated the influence of learning a series of syllable pairs on learning a second series (Peeck,

1979).

However, a number of attempts have been made to actively manipulate prior knowledge or to apply it in the learning process. These relatively recent attempts show that the activation of existing cognitive structures generally exercises a facilitating effect on the learning task. This empirically demonstrated phenomenon awaits sufficient explanation via more applied research. Among other things, it is unclear which cognitive process (or processes) are to be held responsible for this, and how use may be made of this facilitating effect in actual educational situations where increased return and improvement of quality are objectives. In the literature, a number of explanatory theories have been advanced, primarily on the basis of experimental research.

We distinguish eight approaches. Although most of these approaches are called 'theories' in literature, we will introduce them as 'approaches'. Most of them are still hypothetical or just interpretations of experimental results. Nevertheless, some approaches are supported by, or are perhaps a part of generally recognized theories, e.g. the elaboration theory, the subsumption theory. Table 1 gives an overview of these approaches and indicates how prior knowledge influences the learning process. In the remainder of this section, these different approaches will be elaborated.

Table 1: Views of the facilitating effect of prior knowledge during the learning process

Approach	*How does prior knowledge influence the learning process? (key concept)*
1. Restructuring	Information is structured in a different way in the LTM (Structure)
2. Elaboration	The production of elaborations leads to multiple redundant retrieval paths in the cognitive representation (Elaboration)
3. Accessibility	Prior knowledge increases the accessibility of knowledge and consequently the load on the working memory is reduced and more information can be processed per time unit (Rapidity)
4. Selective attention	Attention is directed selectively at passages relevant to prior attention knowledge, which are subjected to a deeper level of processing (Selection, steering)
5. Availability	Prior knowledge increases the availability of information during the learning process and leads to a higher level of retention (Availability)
6. Retrieval-aid	Prior knowledge and access to relevant cognitive structures increases retrieval (Retrieval)
7. Schema-transfer	Prior knowledge implies the presence of relevant schemes, the new information has to be fitted into the right scheme (Connection information-scheme)
8. Representation-saving	Propositions which are part of the prior knowledge no longer have to be encoded. The encoding effort is in consequence considerably reduced (Encoding effort)

4.1 The restructuring approach

First there is the restructuring approach, which assumes that experimental subjects, as a consequence of a period of activation, organize information in the long term memory in a different way from experimental subjects who have no prior knowledge (Matthews, 1982). Although the structure of the original criterion text could be found in the protocols of both groups, the groups differed from one another in a manner in which they had organized the information. A possible explanation for this effect is given by Rothbart et al. (1979) in their 'encoding specificity' theory (Crowder, 1976; Tulving and Thomson, 1973). This theory posits prior knowledge leading to a 'category label' which is activated and to which each specific element is added when it is stored in the memory. The information already present would therefore have an influence on the manner in which new information is coded. A derivative of this restructuring theory is the hypothesis that students with a great deal of prior knowledge process new information by means of a different cognitive structure from those with little domain-specific prior knowledge.

4.2 The elaboration approach or multiple redundant retrieval paths approach

A second option is that prior knowledge stimulates the production of significant elaboration (Mayer, 1980).

Elaboration is the enhancement of information by the development of relations between the ideas in the text (on the basis of prior knowledge) and between an element in the text and prior knowledge. For this reason Mayer (1979) had referred earlier to a similar 'assimilation theory' in which "relating new, potentially meaningful material to an assimilative context of existing knowledge" was regarded as the core of learning. The 'subsumption theory' of Ausubel (1960, 1968) pointed in the same direction: "for effective learning, people should possess and use meaningful assimilative contexts to integrate the material". To make this applicable for all learners, Ausubel introduced the 'advance organizers'. The enhancement of information by elaboration based on prior knowledge leads, according to Anderson and Reder (1979), to the development of 'multiple redundant retrieval paths' in the resulting cognitive representation. The presence of such retrieval paths is supposed to facilitate learning in the sense that the recall of coded information is made easier. The same can be assumed for the production of inference on the basis of prior knowledge. Inference is a meaningful supplement to a text which adds meaning to the incoming information and functions as an expectation pattern in respect of information still to be processed (Schank and Abelson, 1977). The difference between inferences and elaborations lies in the conscious activity which produces the latter. It is also important that the elaboration process leave traces in the recall. As experimental subjects can no longer distinguish the actual information from their elaborations on it as a result of the manner in which they processed the information, the amount of inference in recall increases (Frederiksen, 1975). The presence of such retrieval paths would facilitate learning in the sense that the recall of coded information would be easier.

This approach has often been supported in the literature (Gagné, 1978)[1]. Johnson (1973) found that "linguistic units rated high on meaningfulness were recalled better than those rated low on this dimension". Two criticisms of this research are possible: meaningfulness would seem to be an arbitrary dimension for prior knowledge and it has been shown that the value attached by experimental subjects to the meaning of a proposition was an imaginary value, and thus not valid (Paivio, 1971). Although the elaboration theory gives a possible explanation for the positive effect of prior knowledge on learning, this mechanism has not been either directly or explicitly demonstrated before. It is however true that the research has shown that learning in less successful students can be improved if they are trained to make consistent elaborations and to assess the relevance of self-generated elaborations (Stein, et al., 1982). It is also interesting that Coles (1990) showed that students who adopted an elaborating approach (to relate abstract information to their own concrete experiences) probably acquired a richly structured memory store, facilitating retrieval which became visible through better examination grades.

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[1] Gagné's finding of 'learning-prerequisite sequence' was implemented in the elaboration theory itself (Reigeluth and Stein, 1983)

4.3 The accessibility approach

A third approach concentrates on the speed with which information can be processed as a component of the return on learning. On the basis of the work of Spilich, Vesonder, Chiesi and Voss (1979) and Royer and Cable (1975) it may be posited that the activation of prior knowledge increases access to that knowledge during the learning process. This improved accessibility results in a lessening of the load on the working memory (its capacity consequently increases) and, as a result of this more information can be processed per unit of time.

According to Spilich et al. (1979) people with increased prior knowledge are able to understand a text more rapidly because the prior knowledge is more easily accessed and thus the components of the new information are rapidly linked. Spilich, Vesonder, Chiesi and Voss investigated how students with differing levels of prior knowledge about baseball processed new information on that subject. The use of a specific area of knowledge, such as baseball, had the advantage that on the one hand the researchers were able to give a description of the subject matter using a strict terminology (in terms of goal structure, game states and game actions) and on the other hand that it was fairly simple to divide the students into a High Knowledge (HK) group and a Low Knowledge (LK) group on the basis of a questionnaire after matching.

In this sort of prior knowledge research, it is virtually impossible to form a true control group which has no prior knowledge. The results of the research show that HK-students have a more highly differentiated knowledge structure than LK-students. They have more concepts at their disposal and above all a more highly differentiated system of relationships among these concepts. As a result of this they can identify the knowledge-relevant information more rapidly and more accurately and perceive its relevant importance more quickly, with as a result more precise encoding and storage in the memory, facilitating the recall of data. Further, the HK-group can both qualitatively and quantitatively better anticipate what is likely to happen in a simulated game situation, and, in the retention of the information, they can make better use of the context so that richer and more highly integrated chunks of information are stored in the memory. This results in the prior knowledge available in long-term memory being more easily accessed. Consequently, in functional terms, HK-students have a relatively large working memory capacity for learning knowledge-relevant data (Peeck, 1979). This sort of procedure in research into the effects of prior knowledge on the perception and retention of prior knowledge-relevant information was also applied with remarkable results by De Groot, (1946, 1978) in his research into a chess player's thinking.

Zwarts' (1979) research results accord with the above mentioned findings. The research was directed at the influence of domain-specific prior knowledge in ornithology. The difference between the HK-group and the LK-group was however greater in the free reproduction of a text than on recall with the help of fill-in questions. Anderson and Pichert (1978) believe that "accessibility of information is predictably affected by that prior knowledge". This sort of relationship is also demonstrated by Johnson and Kieras (1983) in their research on subjects in

secondary education, for example history.

This approach is, incidentally, not distinct from the restructuring approach. The manner of organization particularly influences access to information in the long-term memory. One of the relations between accessibility and structure can be identified from the Meyer (1975) and Anderson and Pichert (1978) studies: for students with no prior knowledge on the topic, accessibility of knowledge can be predicted from the text structure; for other students the accessibility is predictably affected by their prior knowledge (figure 4).

Prior knowledge =➢	restructuring of knowledge	different parts are accessible
No prior knowledge =➢		text structure determines access

Figure 4: The relation between prior knowledge and accessibility

4.4 The selective attention hypothesis

A fourth processing strategy that has some a priori plausibility in the explanation of the phenomenon is the selective attention approach, well-known as the selective attention hypothesis. One possibility that cannot be excluded is that people with more prior knowledge direct their attention selectively to passages relevant to prior knowledge in a text, which then receives a deeper level of processing. Prior knowledge activation is said in this sense primarily to fulfill a directive role, in the sense that relevant information receives more attention (largely expressed in study time) at the expense of information that is not relevant to the problem or topic. Goetz, Schallert, Reynolds and Radin (1983) asked experimental subjects to read a text on an empty house and register per sentence how much time they spent on it in order to verify the selective attention
hypothesis. As was the case in Anderson, Pichert and Shirey's (1983) research, the task was to study a text either from the perspective of a potential buyer or from the perspective of a burglar. It was concluded that the information that best fitted the perspective would receive the most attention and would be best retained.

In a number of investigations, similar discoveries were made, i.e. that consistent new information was better retained. Peeck, van den Bosch and Kreupeling (1982) revealed that the hypothesis could also be used to demonstrate that it was precisely inconsistent new information that was best retained. According to Peeck et al. experimental subjects pay selective attention to names that they do not recognize. This was in an activated condition in which the subjects had to name American presidents and states. The fact that inconsistent new information is better retained was also confirmed by others (Srull, 1981).

A number of explanations have been sought for the fact that selective attention is sometimes focused on consistent new information and sometimes on inconsistent information. Berman, Read and Kenny (1983) suggest that the nature

of the task has an influence: when there is a greater demand on the archival memory and there is less useful general social prior knowledge available, inconsistent information is retained less well.
According to Berman et al. (1983) certain experiments conceal a number of elements. The relationship between consistent and inconsistent new information is in itself particularly important. They point to the fact that in experiments in which inconsistent information is best retained, the amount of acquired inconsistent information is relatively small in comparison with the acquired consistent information.

Cohen (1981) notes that the tasks the experimental subjects are given are an influential factor.

One can think here of the differences described in the burglar and purchaser perspectives. Graesser, Woll, Kowalski and Smith (1980) confirm that use of a memory task as a dependent variable leads to the better reproduction of consistent information during a relatively long retention interval. In a memory task the search procedure in the memory is not made easier by 'cues' as in case of a recognition task and is accordingly under less retention pressure (Gerritsen - van der Hoop, 1986). Inconsistent new information is therefore better reproduced in a recognition task (Graesser et al., 1980).

4.5 The availability approach

We stated earlier that availability refers to knowledge that is present, but only retrievable by cueing. This approach states that the effect of prior knowledge can be explained through the fact that more prior knowledge leads to more knowledge available in memory.
Pace (1978) did research into the influence of prior knowledge on information availability. She identified a number of topics which were classified on a scale from 'very well known' to 'totally unknown' in terms of their familiarity to the experimental group. She wrote a text on each of these topics using the knowledge about the prior knowledge of the experimental subjects. Each experimental subject received each text and answered a number of questions on the subject. Pace concluded that the higher the level of prior knowledge the more questions would be correctly answered. This was true for all age groups. Matthews' (1982) results also show that a suitable level of prior knowledge should lead to a higher level of retention. "Finally, prior knowledge will provide a conceptual-peglike construct, thus increasing the amount of information available in memory" (Matthews, 1982). Moreover, he compared the answer to the probe questions with the information from free recall. He concluded that the prior knowledge group had more knowledge available beyond that contained in free recall than did the unrelated knowledge group.

4.6 The retrieval-aid approach

Where the earlier theories were primarily concerned with processing and storing

information, this theory is concerned with the retrieval phase. Anderson and Pichert (1978) established that the activation of relevant cognitive structures after the reading of a text does indeed promote recall of that text and concluded that activation of prior knowledge also influences retrieval. Anderson, Pichert and Shirey (1983) had experimental subjects read a description of an empty house. It appeared that a perspective imposed afterwards also had an influence on post experimental measurement. The positive influence of prior knowledge on retrieval was also found by Berman, Read and Kenny (1983) and Cohen (1981). Rothbart, Evans and Fulero (1979) did not succeed in confirming this effect.

What is called the 'retrieval-aid theory' in literature, encompasses in our view a number of different explanations: the retrieval plan explanation of Anderson et al. (1983), Philips and Lord's (1982) reconstructive processing and Berman, Read and Kenny's (1983) guessing bias idea. Anderson et al. (1983) believe that experimental subjects look for certain information categories which fit into the actual scheme and from which the retrieval plan is constructed. Philips and Lord (1982) give an explanation by means of reconstructive processing: experimental subjects remember some information that is not part of the text presented, but is consistent with the scheme(s) in which the new information is classified. At the retrieval phase, subjects thus try to reconstruct the text, but this is so strongly connected to the scheme in which they integrated the information that parts of the scheme that were not in the text come to surface. The guessing bias explanation of Berman et al. (1983) is perhaps more arbitrary: experimental subjects who cannot remember particular information make guesses on the basis of a given perspective.

4.7 The schema-transfer approach

The schema-transfer approach is based on the important schema-theories. We refer to these as important because they are currently attracting renewed scientific attention. First, the research into text processing has shown that processing and recall of information is strongly related to the activation and use of schemata. Second, research into artificial intelligence is developing representations for knowledge of complex situations, closely related to schemata. Not only there is a renewed interest for these theories, they also take as a starting point the structure of knowledge. This structure seems to be of importance in most explanatory approaches (see table 1). Therefore, we will pay considerable attention to these schema theories which will be used as a basis for certain 'knowledge profiles' in chapter 10.

Schemata as the principle determiner of what will be learned

In cognitive psychological research there have been attempts to understand more about the role of the domain-specific prior knowledge state. With respect to a theory of acquisition, De Corte (1990a) states that a number of characteristics of learning processes have become more and more research-based: e.g. the importance accorded to prior knowledge in general, and informal knowledge and

skills in particular, the need to anchor learning in real life experience, etc. Most of the research into the understanding of new information takes the schema concept as a starting-point. According to Resnick (1981), the notion of a schema as a framework for interpreting the text is central to virtually all of the work on prior knowledge.

The notion of schemata is important for our research, especially as a concept for describing existing knowledge, in which the structure of the prior knowledge is emphasized. Schemata or strongly organized prior knowledge is the product towards which learning and instruction are finally directed (Bransford, Nitsch and Franks, 1977). We assume that understanding schemata can help to analyze a student's prior knowledge, and to picture this analysis along various dimensions in what we will call later on 'knowledge profiles'(see chapter 10). According to Anderson, Spiro and Anderson (1978) "the schemata a person already possesses are a principal determiner of what will be learned...". From the view of the schema-transfer theory, the use of schemata with their several functions gives an explanation for the facilitative effect of the prior knowledge on learning processes.

According to Glaser (1987), in investigating the acquisition of knowledge, there is a need to examine how cognitive structures are modified and combined - how students use prior knowledge in the course of learning.

The schema concept

The notion 'schema' is often defined as an 'abstract knowledge structure' (Anderson and Pichert, 1978a) or 'an abstract description of a thing or event' (Pichert and Anderson, 1977). Rumelhart and Ortony (1977) described schemata in a more concrete way as "data structures for representing the generic concepts stored in memory. They exist for generalized concepts underlying concepts, situations, events, actions and sequences of actions". A direct link between the notion of schemata and the prior knowledge state was given by Neisser (1976). In his perception a schema is that portion of the perceptual cycle which is internal to the perceiver, modifiable by experience, and somehow specific to what is being perceived. The schema accepts information as it becomes available at sensory surfaces and is changed by that information; it directs movements and exploratory activities that make more information available, by which it is further modified.

In order to understand the following theoretical enunciation we will state the following definition of the schema concept. A schema is a basic unit of the knowledge structure, a construct which refers to the format of organized knowledge. It is a fundamental element upon which all information-processing depends. We can imagine it as a unit in which knowledge is packaged. In the next section, examples of schemata will be pictured in a more concrete way.

Schema theories and knowledge representation

In this section, we will give a short overview of the main schema theories and their implications for representing knowledge.

The well-known theories of Minsky (1975) and Rumelhart (1975) concern the

representation of knowledge and the influence of this representation on knowledge acquisition. These two theories show a lot of similarities. Schemata or units of the knowledge structure, containing a model of a situation, are activated through a procedure, comparable with the matching procedure.
Through confrontation with a given situation, the variables in the model are given a value. Variables that do not appear in this concrete situation receive a value based on the schema of the subject. The schema contains such default assignments for each variable. Places filled by default assignments or by incoming information are socalled slots. In other words, schemata are modifiable knowledge structures that represent the knowledge available in our experiences, the interrelationships between objects, situations, events and sequences of events that occur. It contains thus prototypical knowledge about frequently experienced situations and observations (Rumelhart, 1980). The schema theories assume that in the course of learning, a major function of these structures or schemata is the construction of an interpretation of a new situation. Incoming information can be fitted into slots. When enough slots are filled, the schema becomes active. Then it guides and seeks for information to fill the remaining slots and to create a more complete interpretation. Missing information will be completed by defaults or inferences of the subject on the basis of typical knowledge for a particular situation.
Minsky used the notion 'frame' instead of schema. He defined nodes as the singular propositions providing a basic structure to the schema. Slots and fillers represent the different features of the frame. An example of a frame with different slots and corresponding fillers is given in table 2.

Table 2: Slots and fillers in a frame

SUPER FRAME:	creatures			
FRAME:	human			
SLOTS:	age	race	nationality	sex
FILLERS:	29	white	danish	male

A well known basic unit of representation is the proposition. Information can be divided into propositions or expressions (i.e. the smallest unit of text) which can be true or false (Kintsch and van Dijk, 1978).

Schema theories and learning

If a subject's prior knowledge is organized as stated in the schema theories, it follows that this structure must have an impact on the learning process. In this, the Rumelhart and Norman view (1978) is generally accepted. They state that there are three different kinds of learning in relation to their schema theory: accretion, restructuring and tuning.

Accretion is the coding of new information in terms of existing knowledge. Restructuring is the process of creating new schemata (schema induction through the spatial or temporal connection of information or patterned generation through copying old schemata with some adjustments). Tuning or schema-evolution is the slow modification of a schema as a result of handling it in different situations. In this view, again the existing current knowledge is central to the learning process. We now turn to a discussion of these three modes of learning and the conditions under which they occur.

Accretion

Learning by accretion is probably the most common sort of learning. It is also the sort of learning that has least effect on the operation of the system. Whenever new information is encountered, there is assumed to be some schema of the comprehension process laid down in memory. This schema is the basis for recollections. Generally these schemata are assumed to be partial copies of the original instantiated schemata. Thus, these schemata, earlier called memory traces, are assumed to be very much like the original schemata themselves. They differ only inasmuch as they are fragmentary and they have representations for particular aspects of the original situation in place of the variables of the original schemata. Such an accumulation of knowledge is the normal sort of learning. Although the accumulation of a substantial body of knowledge may be necessary for more fundamental kinds of learning, it causes no new schemata to be formed.

Tuning

Tuning involves the actual modification or evolution of existing schemata. There are essentially three ways in which schemata can evolve. First, our knowledge of the variable constraints and default values can be upgraded continuously as we continue to use the schemata. Whenever we find a case in which we determine that a certain schema offers an adequate account of a particular situation, we can modify the variable constraints and default values in the direction of the current experience. As this process continues, it will continue to sharpen the variables and default values to make the schema better represent the population of situations to which it is applied. The second sort of tuning involves replacing a constant portion of a schema with a variable one - that is, adding a new variable to a schema. This sort of schema modification amounts to concept generalization, i.e. making a schema more generally applicable. The third sort of tuning is, in a sense, the opposite of the last one, namely, the process of making a variable into a constant or specializing the use of the concept.

Restructuring

If accretion and tuning were the only learning mechanisms, no new schemata could be created. The third learning mode given previously involves the creation of new schemata. There are basically two ways in which new schemata can be formed: patterned generation and schema induction.

Patterned generation involves the creation of a new schema by copying an old one with a few modifications. Such learning is, in essence, learning by analogy. The second way in which new schemata can be formed is through the process of schema induction. The notion here is that if a certain spatio-temporal configuration of schemata is repeated, there is reason to assume that the particular configuration forms a meaningful concept and a schema can be formed that consists of just that configuration. In order for schema induction to work properly, we must posit some aspect of the system sensitive to the recurrence of configurations of schemata that do not, at the time they occur, match any existing schemata. Such a system is not a natural part of a schema-based system.

The schema-transfer approach explains the facilitating effect of prior knowledge in both the storage of information and the retrieval phases by the presence of an appropriate schema for the textual information. Owing to the fact that the structure for decoding already exists it only has to be related to the new information. The existing schema that is appropriate, has to be transferred to the incoming information. What is called 'remembering by means of a schematic knowledge base' can also operate in the same way.
The conception that memory is composed of an organized entirety of schemata leads to the assumption that schemata have different functions (Brewer, et al., 1984; Lodewijks, 1981; Posner, 1978):

1. to operate as a framework that serves to preserve new information;
2. to influence the amount of attention allocated to a particular type of

information;
3. to produce memory representations that are combinations of old generic knowledge and new incoming information;
4. to serve as a program to guide retrieval processes selectively and in a goal-directed way through the environment;
5. to serve as a framework to guide searches in the human knowledge base while editing;
6. to fill in the gaps in the received information (adequately or otherwise).

Schemata can be thought of as 1) preservation frameworks, 2) selection programmes and 3) production mechanisms. For a detailed elaboration of this functioning and an further explicitation of the structure of knowledge according to the schema theories, we refer to Dochy and Bouwens (1990c).

4.8 The representation-saving approach

A number of authors explain the prior knowledge effect by the phenomenon of representation-saving (Anderson and Bower, 1973, Johnson and Kieras, 1983). What they mean by this is that the more prior knowledge a person has about a subject, the more propositions he has in his memory that are already part of the new information and consequently do not need to be encoded. The effort required for encoding is then superfluous or considerably reduced. Before the encoding of each proposition a check is carried out in order to see whether it is already in the long term memory or not. More prior knowledge leads to a more rapid processing of the information. This hypothesis forecasts the degree of encoding effort, the learning time, and shows a linear relationship with the number of propositions that the experimental subject already knows. This explanation leans, according to Johnson and Kieras (1983), heavily on the elaboration theory.

5 Explanatory approaches to prior knowledge and information-processing

In order to give a clear synopsis of the various explanatory approaches, an overview is given in table 1. In this paragraph, we will draw some conclusions which will be important to our further study. Considering that the various approaches are primarily concerned with phases of information-processing, it seems meaningful to elaborate upon and to try to outline the relations.

It is not our intention to comment on the tenability of these various approaches. This would also not appear to be immediately possible since a number of approaches lean heavily on one or the other or show a degree of overlap. The different approaches are not necessarily mutually exclusive; they are primarily concerned with phases that follow one another in information-processing.

Accordingly, prior knowledge is said to influence each of these phases: the direction of attention, the encoding of information, its processing in the working memory, storage in the long-term memory, and recovery of information from the

long-term memory.

The different approaches recognize the positive influence of prior knowledge on the selection process from the knowledge base, the capacity of the working memory, the elaborations carried out on new information, the storage of new information in the long-term memory and the retrieval of new information.

However, some remarks concerning the research cited in the section above which are of importance for our further research must be made.

It is striking, that in the research referred to, use is made of the activation of prior knowledge but little use is made of the prior knowledge itself. In experimental situations, a short text or task is offered as an independent variable. We are more interested in the impact of students' real and present prior knowledge on the learning process and learning results. Further, virtually all the research into prior knowledge is characterized by a limited ecological validity. This means that the experimental environment is so constructed that the research results cannot be applied to real educational situations. We refer here to the use of nonsense syllables, experiments that use lists of words or one or two short sentences as the information that the student must learn. Also one thinks of the activation of prior knowledge by short passages of text. Sometimes the information to be learnt deals with fictional subjects (for example the American "desert fox"; Peeck, van den Bosch and Kreupeling, 1982) or non-existing situations (for example the balloon study of Bransford and Johnson (1972). Finally the nature of the test (general questions or specific questions on the text, recognition or remembering, etc.) is seldom taken into account in the interpretation of the results.

The supporters of the transfer appropriate processing approach (Morris, et al., 1977) believe that the nature of the test should be considered at every stage. It seems self-evident that varying performances would be achieved if the test were not to relate to the learning task. Although the reproduction of facts is an easy goal it is certainly not the most important and there are many serious objections to a simplistic encouragement of this sort of learning.

Finally, if we outline the various explanatory approaches within the information-processing model, we come to the following picture (figure 5).

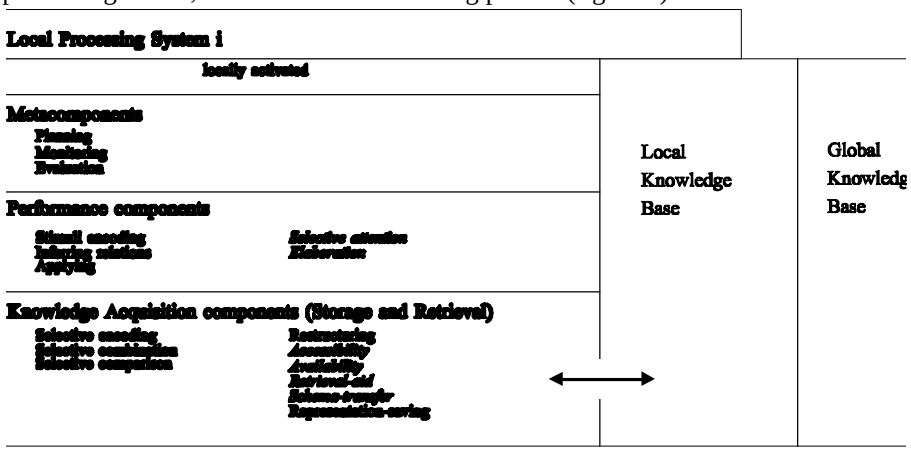

Figure 5: An outline of the position of the various explanatory approaches in relation to Sternberg's local processing system

Figure 5 shows that explanatory approaches related to the effect of prior knowledge can mainly be situated at the knowledge acquisition components level in information-processing. It seems that sifting out relevant new information, maximizing internal coherence of knowledge structures and comparing knowledge structures are the processes where prior knowledge plays a major role. The six explanatory approaches are strongly referring to the structure of prior knowledge. This implies that in investigating students' prior knowledge, we will have to pay attention to structural differences.

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