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The Relation Between Assessment Practices and Outcomes of Studies: The Case of Research on Prior Knowledge

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The purpose of this review was to (a) overview prior knowledge research and its role in student performance, and (b) examine the effects of prior knowledge in relation to the method of assessment. We selected 183 articles, books, papers, and research reports related to prior knowledge. While prior knowledge generally had positive effects on students' performance, the effects varied by assessment method. More specifically, prior knowledge was more likely to have negative or no effects on performance when flawed assessment measures were used. However, in some studies, flawed methods yielded informative results. Thus, in educational research the implications of assessment measures must be considered when examining the effects of prior knowledge.

For many years, educational psychologists have been concerned with the factors that influence performance. In this context, the importance of prior knowledge is often mentioned. Indeed, research has indicated that it is difficult to overestimate the contribution of individuals' prior knowledge (e.g. Alexander, Kulikowich, & Jetton, 1994; Bjorklund, 1985; Chi & Ceci, 1987; Chi, Glaser, & Farr, 1988; Glaser, 1984; Glaser, Lesgold, & Lajoie, 1987; Pressley & McCormick, 1995; Schneider & Pressley, 1989). The last fifteen years of educational research have indicated that the development of an integrated and generative knowledge base rests upon the learner's prior knowledge. That is, prior knowledge is an essential variable in learning (Alexander, Kulikowich, & Schulze 1992; Alexander, Pate, Kulikowich, Farrell, & Wright 1989; Dochy, 1992,1994). Glaser and De Corte (1992), for example, state that "a well-organized and coherent knowledge base initiates inference, conceptualization, and the acquisition

of principled understanding" (p. 1). They do view prior knowledge as a "springboard for future learning" but also note that assessment of prior knowledge can offer valuable information as to the instruction and guidance most needed by an individual (Dochy, 1992). For example, inaccuracies in prior knowledge or misconceptions can be detrimental to future learning if they are not identified and directly addressed (Chinn & Brewer, 1993; Guzzetti, Snyder, Glass, & Gamas, 1993). Thus, this review will examine the effects of prior knowledge, paying particular attention to the role of prior knowledge assessment methods.

Prior Knowledge Terminology

Jonassen and Gabrowski (1993) defined prior knowledge as "the knowledge, skills, or ability that students bring to the learning process" (p. 417). This definition, however, is relatively vague. Other theorists have been equally as vague, using numerous terms to refer to prior knowledge (e.g., current knowledge, world knowledge, expert knowledge, and preknowledge). Prior reviews of the literature (e.g., Alexander, Schallert, & Hare, 1991; Dochy, 1992; Dochy & Alexander, 1995) have also identified the large number of terms available as a problem associated with the knowledge literature. For example, in the English-speaking world, where prior knowledge is most widely studied, the various terms are often used interchangeably. Under the parent term of prior knowledge there is no shortage of offspring, including permanent stored knowledge, prior knowledge state in the knowledge base, archival memory, experiential knowledge, background knowledge, and personal knowledge. For this review, we define prior knowledge as "the whole of a person's actual knowledge that: (a) is available before a certain learning task, (b) is structured in schemata, (c) is declarative and procedural, (d) is partly explicit and partly tacit, (e) and is dynamic in nature and stored in the knowledge base" (Dochy, 1994, p. 4699).

In their review, Dochy and Alexander (1995) stressed that definitional statements are often seen as unnecessary because the meaning of the parent term prior knowledge is commonly understood. We argue that although it is desirable for future research to use a more specific framework of terminology, past research should be approached from a commonly understood point of view. Therefore, in the present study, we began our search with the term prior knowledge and its most commonly used synonyms. While looking at the independent variables reported in the literature, we found a number of terms related to prior knowledge. Some experimenters explicitly state what kind of prior knowledge they are concerned with, while others use the general term 'prior knowledge' or 'background knowledge' and leave it to the reader to conclude what is intended (Byrnes & Guthrie, 1992; Elen, 1992; Neisser, 1976)

It is also important to recognize that prior knowledge can also refer to correct understandings or incorrect, misunderstandings, often referred to as misconceptions. As there is an entire literature devoted to the study of misconceptions and naïve understandings (Chinn & Brewer, 1993; Perkins and Simmons, 1988), we will not focus on these areas in this review. Indeed, previous reviews focusing on misconceptions have revealed that different areas of study assess and address misconceptions differently (Guzzetti et al., 1993). Additionally, there is an extensive terminology used to discuss this form of knowledge. Thus, for this re-

view we only briefly discuss the role of misconceptions on performance. That is, only studies listing prior knowledge as a keyword, not misconception, were included in our analysis.

Assessment of Prior Knowledge

In addition to the terminology used to describe prior knowledge, attention should also be given to the methods used to assess prior knowledge. Snow (1990) and Glaser (1976) believe assessment offers only a snapshot of prior knowledge at a particular point in time, and hence use the term prior knowledge state to express this. Others have also found that a knowledge assessment measure only highlights a portion of what students truly know. In a study by Valencia, Stallmand, Commeyras, Pearson, and Hartman (1991), for example, the authors administered four different types of measures to assess students' knowledge. They found that there were inconsistencies in the correlations among the measures and that different measures elicited different amounts and different types of information. Thus, they concluded that for a more complete characterization of prior knowledge, multiple forms of assessment (i.e., interview and recognition measures) should be used.

Studies have also differed in the type of the prior knowledge that is assessed. For example, some researchers distinguish between different kinds of prior knowledge based on the content characteristics of the assessment measures (Dochy, 1994; Dochy, 1996c). Thus, it appears that the type of assessment used by researchers determines what we know of an individual's prior knowledge. This highlights our concern and stresses the important role of assessment methods. However, after discussing prior knowledge with Tobias (personal communication, 1993), we concluded in the past assessment issues have received little attention in cognitive psychological research, especially in research related to prior knowledge.

To our knowledge, Tobias (1995) was one of the first authors to address the assessment methods of prior knowledge. In his 1994 review of the research on the knowledge-interest interaction, Tobias found that the common variance between prior knowledge and interest is approximately 20%. For this reason, in an experiment on interest and word knowledge he attempted to control for prior knowledge by using two forms of assessment, a metacognitive evaluation procedure (i.e. self estimation of word knowledge) and an objective procedure (i.e. a multiple choice vocabulary test).

In our review of the literature, we noted the kind of assessment techniques used to assess prior knowledge. Based on the types of items we created six categories of assessment: (a) multiple-choice tests (e.g., Chiang & Dunkel, 1992; Joseph & Dwyer, 1984), (b) open questions / cloze tests / completion tests, (c) association tests, (d) recognition tests (e.g., Chiesi, Spilich, & Voss, 1979; Hasselhorn & Körkel, 1986) / matching tests, (e) free recall (e.g., Lambiotte & Dansereau, 1992; Sanbonmatsu, Sansone, & Kardes, 1991), and (f) experimenter judgement (Heit, 1994) and self-estimation (i.e. familiarity ratings) (Afflerbach, 1986). Thus, it appears that prior knowledge is primarily measured using relatively standardized methods (i.e., multiple choice and recognition tests, association methods, questionnaires, checklists, and free recall). The methods used in

the sixth category of assessment, however, are questionable as knowledge is not directly assessed. Instead, the experimenter may control for prior knowledge, assume a certain level of knowledge, or use a form of self-estimation. Heit (1994), for example, controlled prior knowledge by pairing features of persons either congruent or incongruent with prior knowledge. In another study, Pazzani (1991) assumed the content of individuals' general prior knowledge and conducted his experiment under the assumption that everyone thought that "adults are stronger than children" and that "stretching a balloon makes it easier to inflate."

Given the importance of prior knowledge, the abundance of prior knowledge terminology, as well as the various methods used to assess prior knowledge, this review first overviews prior knowledge research and then examines the effect of prior knowledge relative to the assessment methods. That is, we investigate the interaction between method of assessment and the effects of prior knowledge.

Method

Literature Review and Criteria for Inclusion

Before searching the literature for work pertaining to the assessment of prior knowledge, we determined the criteria for inclusion in our analysis. First, the work had to be empirical. Non-empirical literature and literature-reviews were selected in the initial stages of our search to serve as sources of relevant research. However, while these pieces provided a synthesis of prior research, they were not included in the analysis. Second, we decided that participants had to be students in regular education or adults. We were primarily interested in how prior knowledge and assessment interacted in educational practice. That is, we wanted to examine methods commonly used by teachers to assess students' performance. Thus, we did not include studies on the effects of prior knowledge on preschool children or children with severe disabilities. The third criterion for inclusion was a clear description of the characteristics central to our analysis. Therefore, to be included studies had to clearly describe the variables, treatment(s), and outcome(s), as well as define what was meant by prior knowledge and indicate the means of assessment.

Search Procedure

We conducted our search of the literature using a three-step method. First, searches were conducted in a computerized database, the Educational Resources Information Center (ERIC) catalogue, according to keywords related to prior knowledge . These searches were conducted three times per year in every year since 1987. The Current Contents (for Social Sciences) was also searched with comparable keywords and relevant conference papers were collected. These searches yielded 75 articles, conducted between 1978 and 1994, that fit the criteria for our review.

In our second search of the literature, we defined the additional keywords to be used to select literature from the ERIC catalogue from 1980 to 1997. We decided to combine *prior knowledge* and related terms with concepts related to *test* and *assessment*. These terms included *placement assessment, continuous*

assessment, and *diagnostic assessment*. Using combinations of these terms, 1256 titles were identified. Review of titles and, if necessary, the abstracts, however, resulted in the initial selection of 37 articles. Closer examination of these articles yielded 24 that qualified for inclusion in our review.

For our third search of the literature, we employed the snowball-method, reviewing the references in previously collected articles for additional works. Review articles and theoretical overviews were also gathered to check their references and assemble the underpinnings of our theoretical framework. We also conducted a final search in Psychological Abstracts, PsycLIT Journal Articles, and PsycLIT Chapters and Books. Because of the thorough previous searches, we decided to restrict this search to publications after 1980. In our view, this search would reveal the most recent literature. This inquiry yielded 84 articles that fit our criteria.

The search resulted in a total of 183 empirical studies. While the number of studies not included in the analysis is quite striking, this drop out in the selection procedure is to be expected for two reasons. First, our criteria were not easily met by authors, especially the third criterion. Very few authors explain what they mean by the term prior knowledge or give an adequate description of the methods used to assess prior knowledge. Certainly, the latter was important to our study. Second, prior knowledge seems to be a popular keyword. Many studies that used prior knowledge as a keyword investigated retrieval or the learning process and merely hypothesized that prior knowledge played a role in their results. Other studies listed prior knowledge as a keyword, but upon reading the abstracts and articles it was unclear as to why prior knowledge was used as a keyword. Thus, there seems to exist a certain common sense that prior knowledge is an important asset in learning. However, the number of studies that explicitly address prior knowledge is much smaller that one would initially expect.

Coding Study Characteristics

Using other literature reviews as a guide (Alexander et al., 1994; Falchikov & Boud, 1989), we defined the characteristics central to our review and analyzed the articles we selected on the basis of these characteristics. Specifically, we recorded the following information in tables:

*the author(s) and the year reported;
*the type of publication;
*the type and number of subjects;
*the independent and dependent variable(s);
*the domain and characteristics of the task;
*the treatment;
*the method of prior knowledge assessment;
*the methods of analysis and the statistical values;
*the principal research outcome(s).

In coding this information and constructing our overview tables, we used the following guidelines:

Independent variable. Our review of the literature revealed that different names

were used to refer to the prior knowledge as an independent variable. For example, Alexander, Gillingham, and Kulikowich (1990) used the variable-name *group* to distinguish between subjects with high and low domain-specific prior knowledge. Others used synonyms of *prior knowledge*. In this review, we use the terms *prior knowledge* as the variable-name to leave no doubt about what is intended.

With respect to when prior knowledge was measured, all prior knowledge tests in this research review are considered pretests. In a strict experimental sense, a pretest is the same test or an alternate form of the posttest (Campbell & Stanley, 1966). This, however, is not always true of the pretests in this review. The research reports were not always clear whether an experimental pretest-posttest design was used. Some experimenters explicitly refer to their prior knowledge test as a pretest while others do not. Thus, for the purpose of this article, we view all prior knowledge tests applied before the experiment or treatment condition, as pretests, although they may not be in the context of a strict experimental pretest-posttest design.

Principal outcome(s) of the research. Only the outcomes related to prior knowledge or progress testing are mentioned. Some studies have examined the effects of many learner and learning environment characteristics, such as interest (Alexander et al., 1994), beliefs (Alexander & Dochy, 1995), or motivation (Boekaerts, 1986). Although these characteristics are all stated as independent variables, we do not discuss their possible effects on the principal outcomes. Additionally, only the main effects of prior knowledge are considered. For example, in Lipson's (1982) study the main effect of prior knowledge was positive, whereas additional analysis revealed that wrong prior knowledge negatively influenced performance. In this case, only the positive effect was counted. Finally, when more than one experiment pertaining to prior knowledge was described in an article, the experiments are discussed separately.

Synthesizing Research

There are three methods to review literature: narrative reviews, quantitative methods, and meta-analyses. These methods have changed dramatically over the last decades. Narrative reviews are qualitative descriptions of the findings from literature. The integration of literature is mainly an intuitive process of the reviewer. By reading the studies carefully, he or she seeks patterns in the results, and reports them in a narrative style. These reviews rely in the interpretation abilities of the reviewer, since no 'objective' mathematical methods are used. Therefore, it is important to specify the method used to integrate the findings as clearly as possible. Fisher (1932) was one of the first to apply quantitative methods to literature reviews. This method utilizes elementary mathematical procedures for synthesizing research studies (i.e., like counting frequencies into box scores). The findings from this form of analysis are easily verified. Therefore, they are more objective but give less in-depth information than a narrative review.

Glass (1976) later systematized the approach of quantitative procedures and introduced the term meta-analysis. An important advantage of a meta-analysis is that studies can vary substantially and still be integrated without being greatly influenced by the interpretation of the reviewer. Glass (personal communica-

tion, 1995) points out that a meta-analysis in our field of study is not easily done. "The notion of a variable as loosely defined as 'preknowledge' giving a numerical answer to the question 'How much variance does it account for?' is a bit of a problem. [...] It doesn't mean a meta-analysis won't work; it simply means that care has to be exercised in coding the conditions" (p. 1). Therefore, to accomplish the goals of this review we will give a narrative review of the literature. This conventional literature review requires the careful reading and integration of separate studies.

Structure of this Review

This narrative review will be structured into two main parts. First, we will provide a brief overview of prior knowledge research, discussing the characteristics of prior knowledge and the role of prior knowledge in performance, as demonstrated by commonly used statistical techniques (correlational, causal modeling, and path analysis). Second, we will more closely examine the effects of prior knowledge in relation to the assessment measures employed in the different studies. This section will begin with a discussion of the validity of the assessment techniques and the main problems associated each form of assessment. We will then proceed to describe the assessment techniques used in studies finding no, negative, or positive effects of prior knowledge on performance. Before concluding, we will also briefly address the role of progress assessment.

Results

In this review, we wanted to overview prior knowledge and describe the effects of prior knowledge from an assessment point of view. This implies the unraveling of effects and their assessment methods, which is not an easy task. The negative effects of prior knowledge, in particular, appeared to be strongly related to the assessment technique. Thus, in our results we will begin by giving a brief overview of prior knowledge research followed by a more extensive discussion of the effects of prior knowledge related to the form of assessment.

Overview of Prior Knowledge

Characteristics of Prior Knowledge

Before discussing the effects of prior knowledge on students' performance, it is important to consider the characteristics of prior knowledge. Figure 1 displays the model Dochy (1992) used to characterize a person's prior knowledge state. In this model, the qualities of prior knowledge are assumed to interact. Many experiments have been conducted to clarify one or more of the relations shown in Figure 1. Byrnes and Guthrie (1992), for example, found that prior knowledge can indirectly effect performance through the clarity of study materials. They found that prior conceptual knowledge expedited students' textbook search for the answers to questions about the text. Chan, Burtis, Scardamalia, and Bereiter (1992) also showed that prior knowledge exerts its effect on learning through the mediating role of constructive activity. Overviews of such explanatory theories can be found in Pressley and McCormick (1995) and Dochy (1990).

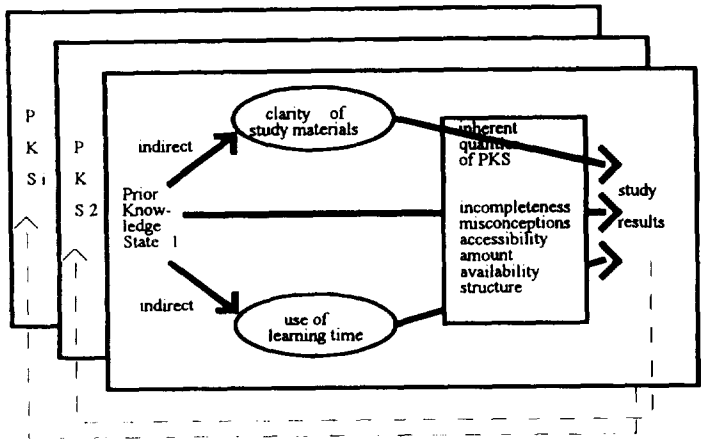

FIGURE 1. *Interaction effect involving inherent qualities and the facilitating effect (adapted from Dochy, 1992)*

In discussing the inherent qualities of prior knowledge it is generally assumed that a students' prior knowledge' is "reasonable complete and correct, of reasonable amount, of good accessibility and availability, and well structured" (Dochy, 1992, p. 26). This assumption however, is not always true as students often have misconceptions and knowledge that is not well-structured.

The study of misconceptions and naïve understandings occupies its own unique place in the knowledge literature. While some researchers disagree as to how such misunderstandings are to be conceptualized—as naïve theories, misconceptions, or primitives—their role in student learning, particularly in science, has been well documented (e.g., Alvermann & Hague, 1989; Alvermann & Hynd, 1989; Biemans & Simons, 1994; Pazzani, 1991). Of particular concern is students' resistance to alter their views even when presented with plausible evidence that provides a more adequate account of a phenomena. Thus, prior knowledge may actually hinder the learning process (e.g., Cohen, 1981; Hynd & Alvermann, 1989; Lipson, 1982). Theorists have attempted to characterize students reactions to information inconsistent with their prior knowledge and have suggested instructional techniques to promote conceptual change (Chinn & Brewer, 1993; Perkins & Simmons, 1988). Often such techniques involve creating cognitive conflict within the individual, thereby forcing them to reconcile the differences between the new information and their existing knowledge (Guzzetti et al., 1993). Pintrich, Marx, and Boyle (1993) also stress that motivational factors, such as the individual's goals and interests as well as their self-efficacy and control beliefs, play an influential role in encouraging students to restructure their knowledge and revise existing conceptions. The authors also speak of the paradoxical role of prior knowledge. On one hand, inaccurate knowledge can be resistant to change and hinder the learning of new information. At the same time, students with little or no prior knowledge of an area are lacking the necessary knowledge frameworks. Thus, they have difficulty in structuring and judging the validity of new information (Pintrich et al., 1993).

However, research would suggest that explicitly addressing misconceptions in instruction may help individuals restructure their knowledge and correct their naive conceptions (Biemans & Simons, 1994). One way to address students' misconceptions is to alert them that the new information may conflict with their existing ideas. For example, in one study Alvermann and Hague (1989) warned students that the new information was inconsistent with their prior knowledge—referred to as the augmented activation of misconceptions—and compared them to students whose misconceptions were activated without warning. They found that students in the augmented activation condition achieved better learning results than those who were not. Other studies have had demonstrated similar findings and have also suggested that no activation of misconceptions may actually result in better learning than merely activation of misconceptions (Alvermann & Hynd, 1989; Hewson & Hewson, 1983; Hynd & Alvermann, 1989). Thus, it appears that to prevent students from resorting to strategies that allow them to preserve their misconceptions, they must be directly confronted with the inconsistency and presented with a plausible alternative (Guzzetti et al., 1993).

Activation of misconceptions and prior knowledge in general is also a matter of availability and accessibility of prior knowledge. Spires, Donley, & Penrose (1990) showed that providing students explicit instruction on how to activate prior knowledge during reading had a positive affect on student's ability to answer application level problems. Mathews (1982), for instance, found that different (not merely more) information was accessible to the groups with high and low prior knowledge, and that more information was available to the prior knowledge group. Minnaert and Janssen (1990) conclude that the availability and accessibility of prior knowledge is a determinant of study efficiency.

We proposed that the availability and accessibility of prior knowledge may be related to another quality of knowledge that experimenters are frequently concerned with—the structure of prior knowledge. In her work, examining knowledge in novices and experts, Chi and colleagues have found that that there are differences in the organization and structure of information as well as the amount (Chi, Feltovich, & Glaser, 1981; Chi, Hutchinson, & Robin, 1989). Experts tend to structure their knowledge hierarchically, organizing their knowledge into groups which are locally cohesive. This structure in turn allows individuals to make greater use of what they know. Pearson, Hansen, and Gordon (1979), for example, found that individuals with well-developed schemata on a topic answered more question correctly than individuals with weakly developed schemata. The study of Smith (1992) also supports the idea that experts in a domain develop a mental organization that facilitates the daily use of that knowledge. However, one should also keep in mind that even within a group of experts the mental structure of knowledge can vary (Körkel & Schneider, 1989).

From this, we see that while the quantity of prior knowledge may directly impact one's study skills, there are other characteristics of knowledge that may also influence learner outcomes (Dochy & Alexander, 1995).

The Role of Prior Knowledge

A multitude of investigations has shown that prior knowledge is an important variable affecting study results (Bjorklund, 1985; Bloom, 1976; Bransford, Nitsch

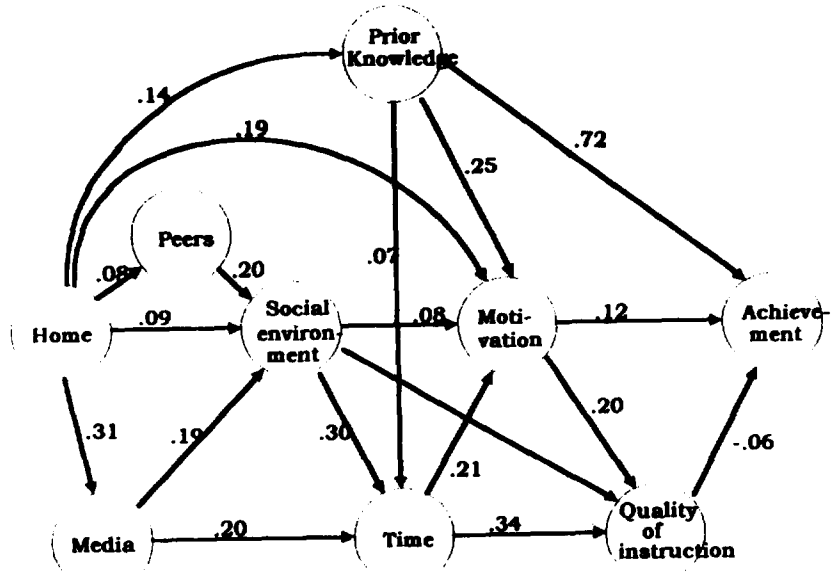

FIGURE 2. *Complex causal model of educational achievement (free after Parkerson et. al., 1984)*

& Franks, 1977; Chi & Ceci, 1987; Chiesi et al., 1979; De Corte, 1990; Dochy, 1992; Elen, 1992; Pressley & McCormick, 1995; Schneider, Körkel, & Weinert, 1990; Tobias, 1994; Walker, 1987). Also, in psychological models of educational performance, prior knowledge plays a major role (for an overview, see Haertel, Walberg, & Weinstein, 1983). This over-all impression is that the results appear to be stable, regardless of the method of analysis. Thus, before examining the role of assessment we will briefly overview some of the main findings offered by these different forms of analysis.

Prior knowledge and explained variance in post-test scores. Several investigations have demonstrated that prior knowledge is potentially an important variable contributing to the explanation of post-test variance (Bloom, 1976; Dochy, 1992; Tobias, 1994). That is, prior knowledge is one factor that can be used to explain individuals' performance on post-test measures. Concrete results were reported by Bloom (1976), who found correlations of 0.50 to 0.90 between pretest and posttest scores. He used these correlations to deduce the amount of explained variance. This work revealed that pretest scores explained between 25% and 81% of the variance in posttest scores. In ecologically valid settings (i.e., real -life classroom settings), Dochy (1992) found that prior knowledge state tests could explain up to 42% of variance in performance. Tobias (1994) speaks of 30 to 60% of explained variance. This range can certainly be explained by the influence of the research environment (i.e. real life settings compared to experimental settings) and by the differences in domain-specificity. Investigations focusing at domain-specific knowledge will reveal clearer results (expressed in a higher percentage) than studies aiming at domain-tran-

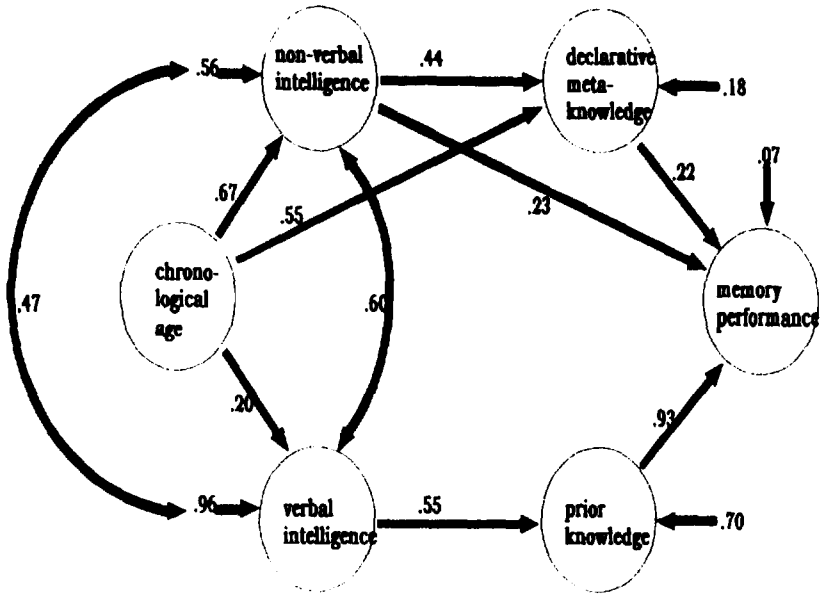

FIGURE 3. *LISREL model of structural relationships (after Körkel, 1987)*

scending knowledge (Dochy & Alexander, 1995). Despite these differences, the results of these investigations reveal that prior knowledge generally explains a considerable amount of the variance in performance (see also Tobias, 1994). Some studies have even shown that prior knowledge explains a greater amount of variance that other variables (Resnick, 1981).

Prior knowledge and causal modeling techniques. The use of causal modeling to explore educational performance has resulted in complex models with good over-all fit and a multitude of significant structural coefficients, stressing the importance of prior knowledge. For example, Parkerson, Lornax, Schiller, and Walberg (1984) found that a simple productivity model was inadequate because of a general lack of fit and many nonsignificant structure coefficients. Instead, their complex model (Figure 2), which stressed the importance of prior knowledge, had a good overall fit and a multitude of significant structural coefficients. (However, caution is needed in interpreting correlations within causal path models as the negative correlation in Figure 2 could be caused by students critical of instruction.) In an analysis of the relationship between age, intelligence, metacognition, prior knowledge, and performance, Körkel (1987) also found that prior knowledge played an important role in performance. The structural relationships among these variables are displayed in Figure 3.

There is also considerable evidence that domain-specific prior knowledge is the type of prior knowledge that mostly affects the learning process and results. In a replication study, Weinert (1989) found that domain-specific knowledge was a decisive prerequisite for good mathematics performance. However, it is important not to confuse domain-specific prior knowledge with the overall gen-

eral ability, or intelligence. In the fifties, it was believed that more intelligent people could learn things that less intelligent could not. A careful inspection of empirical findings raises doubt as to the truth of this statement. First, the correlation between intelligence and performance is highly variable. Statistical meta-analyses have yielded overall coefficients that range between .34 and .51, indicating that intelligence explained between 12% and 26% of the variance in performance. Second, if one partials out the influence of prior knowledge, the correlation between intelligence and study result is drastically reduced (Weinert, 1989). To the contrary, if intelligence is partialed out, the correlations between prior knowledge and performance remain significant. From these findings it appears that domain-specific knowledge can compensate for low intellectual ability, but a high intellectual ability cannot compensate for a low prior knowledge (Walker, 1987; Weinert, 1990).

We feel that the most important finding from these studies employing causal models is the superior explanatory power of prior knowledge. That is, in the studies we have discussed, prior knowledge is the most significant path in the models. Thus, intra- and interindividual differences in cognitive performance seem to be the result of differences in the knowledge base. If this is the case than, indeed, the past is the best predictor for the future (Weinert, 1990).

Prior knowledge, path analysis, and variables influencing performance. Continuing our discussion of the findings offered by different forms of analysis, we found that studies using path analyses reveal a great deal about the direct and indirect effects of prior knowledge as well as mediating variables. Path analyses were conducted by Chan et al. (1992); Chandran, Treagust, and Tobin (1987); Gijselaers and Schmidt (1985); Hasselhorn and Körkel (1986); Körkel and Schneider (1989); Lawson and Worsnop (1992); Minnaert and Janssen (1992, 1995); and Murray-Harvey and Keeves (1994). As expected, most studies found causal relationships with high values between prior knowledge and performance. These studies also reveal less expected relationships. For example, one variable, which has not been mentioned before, is prior educational performance. That is, the education a student completed before entering a new education or learning environment had a direct effect on performance ranging from .21 to.71. Prior educational performance also had an indirect effect on performance via prior knowledge, learning strategy, and procedural metacognitive knowledge (ranging from .21 to .53). The high correlations between prior knowledge and speed and accuracy of study behavior (.53 to .58) are quite amazing as well. This last variable influences performance indirectly through learning strategy, as one could expect (.10 to .52). While only mentioned in two studies (Körkel & Schneider, 1989; Murray-Harvey & Keeves, 1994), age and intelligence also seem to have direct and indirect effects on performance. However, the highest value in all of these models is the relationship between prior knowledge and procedural metacognitive knowledge (between .30 and .80). Thus, one reason for the importance of prior knowledge appears to be the resources it provides the student.

Assessment and the Effects of Prior Knowledge

Now that we have briefly discussed the nature of prior knowledge and its role

in performance we will examine the interaction of assessment and the effects of prior knowledge more closely. We begin with the types of assessment procedures we found in the literature, discussing issues of external validity and problems or flaws we see with these methods. This is followed by a discussion of the assessment procedures used by studies indicating that prior knowledge had negative or no effects on performance as well as studies those studies that identified the positive effects of prior knowledge. We conclude this section with a brief discussion of the role of progress assessment.

External Validity and Assessment Problem in Measuring Prior Knowledge

Slavin (1986) argues that the external validity of a study is an important factor to take in to account when considering a study for a review. He provides examples of reviews which found highly positive effect sizes, but included extremely brief artificial experiments or studies with very small sample sizes. We consider the assessment format used to assess the effects of prior knowledge to also be a factor influencing the external validity of a study. Thus, given the wide range of measures used to assess prior knowledge, we decided to make distinctions among the types of assessment measures we encountered. In our initial review of the literature we noted six types of assessment: (a) multiple-choice tests (e.g., Chiang & Dunkel, 1992; Joseph & Dwyer, 1984), (b) open questions / cloze tests / completion tests, (c) association tests, (d) recognition test (e.g., Chiesi et al., 1979; Hasselhorn & Körkel, 1986) / matching test, (e) free recall (e.g., Lambiotte & Dansereau, 1992; Sanbonmatsu et al., 1991), and (f) experimenter judgement (Heit, 1994) and self-estimation (Afflerbach, 1986). Some of these methods are questionable as knowledge is not really being assessed but instead assumed. Thus, upon closer examination of the methods we categorized the forms of assessment based on their external validity. Multiple choice tests, open questions, cloze tests, completion tests, recognition tests, and matching tests are considered to be externally valid measures of prior knowledge, since they are widely used in classroom practice. Free recall can be considered a method which is less objective, but still frequently used in research because of its possibilities of in-depth investigations. Experimenter judgement and self-estimation measures, however, are seen as non-objective, unreliable, and less valid methods.

We acknowledge that each method listed has problems, but from the assessment methodology point of view, a few remarks should be made. As we argued earlier, multiple choice tests, open questions, cloze tests, completion tests, and recognition tests vary in their degree of validity, but all do have a reasonable level of validity and objectivity (Glaser & Silver, 1994; Moerkerke, 1996). More problems, however, come to the surface when we consider flawed assessment methods—matching tests, interviews, free recall, assumption, and familiarity ratings or self-estimation of prior knowledge. Matching tests are conceptually very simple. One might even question their validity. However, they offer more information on the structure of one's knowledge base than its content. Also, fatigue may influence results as studies often involve formidable numbers of comparisons (Schneider & Pressley, 1989). Interviews and free recall are also questionable as they are influenced by the subject's verbal abilities.
Moreover, the data analysis is conducted by means of a subjective interpreta-

tion of written or audio reports.

Assumptions, familiarity ratings, and self-estimations are also prone to subjectivity. It has been argued that estimations are made inconsistently, varying with material and task familiarity (Schneider & Pressley, 1989), thus, making them unreliable. Dochy (1992) found that students who possess a large amount of prior knowledge, assessed by means of an objective test, were likely to estimate that they had little prior knowledge. On the other hand, students with little prior knowledge were likely to rate their own knowledge high. This phenomenon was explained by the fact that students who are knowledgeable in an area know what they do not know and, therefore, think that the missing prior knowledge is quite large. The opposite is true for individuals with low levels of prior knowledge. Thus, as we examine the effects of prior knowledge it is important to consider the form of assessment being used by the researchers.

Negative or No Effects of Prior Knowledge

While the majority of the studies we examined for this review (91.5%) demonstrated the positive effects of prior knowledge on performance, 11 studies indicated that prior knowledge had negative or no effects on performance. We will begin our discussion with these studies as we think a closer examination might reveal interesting findings and new explanations for the absence of positive effects.

Three out of five studies, in which no effect of prior knowledge was observed, state that the groups they compared did not differ greatly in terms of prior knowledge. However, a closer reading of these three studies reveals some interesting findings and explanations for why the researchers did not find significant effects. For example, Hammadou (1991) did two parallel studies in French and Italian, trying to find out whether familiarity with the topic influences reading proficiency. The author states that research studies have operationalized prior knowledge in a number of different ways. Her approach was to maximize probable prior knowledge differences by selecting topics from different parts of the text. Subjects were asked rate their familiarity with each of the topics using a three point scale. In this way, the researcher assumed that familiarity was an indicator of the subjects' prior knowledge. However, the study found that the topic judged most familiar was the passage subjects has the most difficulty recalling. From this the author concludes that the subjects' rating of their own familiarity with a topic was unable to predict their ability to comprehend what they read about that topic. While the author states that she is aware of the weakness of her method. the manner in which prior knowledge was measured makes an important difference in the results. One could even question if familiarity implies prior knowledge. An additional weakness of this method may be inaccuracies in the subjects' self-reporting that topic A is more familiar than topic B.

In her previous work (Hammadou, 1988), the author found significant positive effects of prior knowledge on readers' comprehension. However, there she used objective multiple-choice tests and piloted them with a large group of experts and novices to ensure their reliability and validity. While such procedures are time-consuming and costly, the alternative of simple self-report on familiarity does not appear to be a fail-safe shortcut.

Schiefele's 1990 study focused on the role of interest. Therefore, the topic was selected to ensure a large difference in subjects' interest and little difference in subjects' prior knowledge to prevent any confounding of interest and prior knowledge. The author later admits that future studies should examine the effects of differing levels of prior knowledge. Additionally, this study suffered also from weaknesses in the assessment methods. Prior knowledge was assessed by five open-ended questions, a comprehension test consisting of 12 open-ended questions, and an association test using the stimulus term emotion. For the open-ended questions, we were surprised that raters amended their answer key after scanning the subjects' responses. This appears to contradict the rating procedure of defining the correct answer before reading responses. Schiefele also questions the validity of the prior knowledge test and proposes this as a possible explanation for his findings. That is, it is possible that subjects had prior knowledge but that it could not be assessed with the measures Schiefele used. Surprisingly, and contradictory to the statistical findings, the author concludes that his study and the studies of others (i.e., Baldwin, Peleg-Bruckner, & McClintock, 1985) indicate that the correlation between interest and comprehension is dependent on prior knowledge. From his present study, Schiefele derives that for topics where subjects have little or no prior knowledge, the level of interest plays a more important role.

Schnotz (1994) also took prior knowledge into account in an investigation of differences in strategies for learning a complex subject matter from hypertext. This study found virtually no difference in prior knowledge between the groups. However, this study assessed prior knowledge on the topic Time and Date by interviewing students, and then counting and analyzing the number of domain-specific concepts they used to answer the questions. One could question if this method involves too much coincidence in naming concepts. Or perhaps these concepts were too straightforward. Schnotz notes that while in other studies learners with higher prior knowledge were generally better able to find and process information from hypertext (e.g., O'Donnell, 1993), he did not observe such an effect because there were no prior knowledge differences between his groups.

Other studies also reported that prior knowledge does not effect performance. Walraven and Reitsma (1992) investigated the influence of prior knowledge activation. While the authors noticed a trend in favor of the knowledge activation condition this finding was not confirmed in the statistical analysis. Some remarks can be made here. First, activating prior knowledge is a complex issue. Researchers often assume that activating prior knowledge results in a state where the required prior knowledge is present. However, previous research has shown that certain inherent qualities of prior knowledge are prerequisites for this premise (Dochy, 1992). Certainly the accessibility and availability (see also Figure 1) play an important role. Moreover, the instruments and selection of subjects certainly influence the research results. By answering the question "What do I know already about the subject?" pupils were supposed to activate their prior knowledge. Additionally, the tests used as dependent variables did not ask explicitly for prior knowledge. Thus, one cannot expect a large effect from these measures. Finally, the subjects in this study were selected based on their poor reading comprehension scores. Prior knowledge activation may not have been

possible for these poor readers.

From our analysis of studies finding no effects of prior knowledge on performance, another interesting finding emerged. Specifically, the nature of the task appears to influence the effect of prior knowledge. In an investigation of the cognitive and motivational processes triggered by prior knowledge, Morris, Tweedy, and Gruneberg (1985) investigated the correlation between prior knowledge of soccer teams and the recall of real and simulated scores. That is, the authors hypothesized that if high soccer knowledge subjects performed similarly for the two types of scores it would imply that the processes leading to better recall do not depend upon implications of the scores. On the other hand, different results for the two types of scores would imply that knowing the scores are real stimulates the interest of the knowledgeable subjects and encourages them to process the implications of the scores. Assessing prior knowledge with a 30 question objective test and a free recall test, the authors found that there was a significant correlation between prior knowledge and recall of real soccer scores. Additionally, the high knowledge group was only at a slight advantage with the simulated scores. The authors conclude that "not only past knowledge of teams is required, but it must be activated by the knowledge that the results are actual ones with real implications" (p. 419). These findings support the trend in education to involve more real life situations in learning such as in problem-based learning or powerful learning environments (Dochy, 1996a; Dochy, 1996b; Segers, Dochy, & DeCorte, in press) and to use alternative or authentic forms of assessment (Birenbaum & Dochy, 1996). However, the results also highlight a problem related to simulating real-life situations. Even though there was no face difference between real and simulated scores, the simulation did not initiate the same cognitive processes.

In our review of the literature, we also found several studies indicating negative effects of prior knowledge on performance. In Lipson's study (1982), the negative effects were caused by inaccuracies in prior knowledge. While subjects' recall was strongly affected by prior knowledge, as assessed by true/false statements and a post-reading recognition task, there were differences in the responses given. More specifically, people were more likely to answer correctly on the posttest when they did not know the answer earlier than if they had answered wrong at pretesting. Even when inaccurate prior knowledge was contradicted by new information, individuals used their prior knowledge while answering questions on a posttest. This suggests that subjects relied more heavily on their prior knowledge than they did on the text. Even so, prior knowledge explained a major source of variance in posttest performance. Thus, individuals were better at acquiring totally new information than at correcting inaccurate information. That is, prior knowledge supports learning only when it is correct, suggesting that it may be better to have no prior knowledge that wrong prior knowledge.

Similar effects were observed in a study by Ceci, Caves, and Howe (1981), where distortions in delayed remembering could be predicted from individuals' prior knowledge. The authors found that when new information is clearly incongruous with one's preconceptions, although immediate recall may be correct, a shift will occur in delayed recall. Consequently, after several weeks the contents of recall displays a major shift towards prior incorrect knowledge.

The findings of Alvermann, Smith, and Readance (1985) support the Lipson and Ceci et al. findings that knowledge from text is rarely used to update existing knowledge, "especially when that knowledge conflicts with information in the text" (Alvermann et al., 1985, p. 434). The authors activated prior knowledge of one group and found that it interfered with, rather than facilitated, reading comprehension. They suggest that inaccurate prior knowledge or misconceptions may have been activated when the text contained information incompatible with the students' prior knowledge. Both groups of students performed similarly on the multiple-choice test. However, when these questions were broken down according to the information addressed (i.e., compatible or incompatible with prior knowledge) students' whose prior knowledge was not activated performed better on the incompatible items than students whose prior knowledge was activated.

Two additional studies indicated that individuals with less or no prior knowledge learned more than their more knowledgeable counterparts. Marshall (1985) found that recall was more complete for individuals who had no relevant prior knowledge. She explained this by speculating that the intrinsic value of the information to the reader may be more important than prior knowledge of the specific information. For example, readers recalled more from a text that they rated as "very important." Readers also seem to use structural cues to identify the importance of the text. However, once they had an appropriate schema for reading or perceived immediate value in the text, their prior knowledge "seem[ed] to be the primary source for thinking about the textual content"(Marshall, 1985, p.94).

In a study by Neuman (1989), pretest scores were negatively correlated with knowledge gain ($r = -0.57$), that is, the difference between pretest and posttest scores. From this, he concludes that students learn more if they enter the course knowing less. However, it is important to note that the use of knowledge gain scores. Neuman (1989) explicitly defines performance as "demonstrating mastery (e.g., a correct answer to a multiple choice question)" and learning as "a gain in knowledge (the difference between what is known on the first day and on the last day of the course)" (p.19). Neuman concludes in this way that prior knowledge (pretest score) and general ability (GPA) predict learning to a large extent.

Finally, Anderson (1981) also investigated the effects of prior knowledge. While his method and instruments are questionable (using lists of famous people; a prior learning phase; name familiarization phase; location learning; name-location recognition; measurement of reaction time in milliseconds), it is noteworthy that he differentiates between the effects of experimental and pre-experimental knowledge. He found that experimental knowledge, that is, prior knowledge provided by the experimenter, provides benefits, but also costs in terms of longer reaction times. To the contrary, pre-experimental knowledge, that is, prior knowledge a subject had before entering the experiment, only benefited the subject. From this it appears that pre-experimental prior knowledge has qualities different from knowledge learned in one-hour for an experiment.

This analysis suggests that prior knowledge has negative or no effects on performance if the measures are flawed or inadequate in assessing differences in individuals' knowledge. For example, the use of familiarity ratings do not ap-

pear to be an efficient estimation of prior knowledge. These studies also suggest that negative or no effects are likely to result if students' prior knowledge is inaccurate, or if students do not differ in their prior knowledge of specialized issues. Thus, in studying the effects of prior knowledge it is essential to consider the way prior knowledge is assessed as well as what kind of prior knowledge is being activated by the task.

Positive Effects of Prior Knowledge

As previously state, the majority of the studies we identified reported positive effects of prior knowledge on performance. As with studies that indicated prior knowledge had negative or no effects on performance, several of the positive effect studies used flawed assessment techniques. Thus, we will discuss these studies first, before describing studies that used what we feel are more valid and reliable forms of assessment.

Positive effects of prior knowledge: Flawed assessment method. The previous section suggests a rather strong relationship between using flawed assessment methods and finding no or negative effects of prior knowledge. Subsequently, this leads us to the following question: Do studies using flawed assessment techniques find positive effects? In reviewing the selected studies, we coded for the objectivity of the prior knowledge assessment measures. We found 15 studies (in 11 publications) that reported positive effects and appeared to have used flawed measures of prior knowledge.

An overview of these studies is presented in Table 1. Nine out of the fifteen studies controlled for prior knowledge by having subjects read different texts, by choosing novices and experts, or by giving subjects different lectures (Afflerbach ,1990; Britton & Tesser, 1982 [3 experiments]; Chiang & Dunkel,1992; Johnston & Pearson,1982; Mathews,1982; Willoughby, Wood, & Kahn,1994 [2 experiments]). Thus, there is no reason to speak about flawed assessment because knowledge was not assessed. Instead, the researchers found positive effects for prior knowledge because they were investigating the facilitating effect of prior knowledge. Subjects with (controlled for) high prior knowledge constructed the main ideas from a text more often and were able to recall more information. Some of these experiments provided evidence for explanations of the facilitating effect such as the representation saving hypothesis and the encoding effort hypothesis (Dochy, 1992).

The study by Afflerbach (1986) should be mentioned here as we classify it as a study that controlled for prior knowledge. Afflerbach used a selection procedure to find chemistry and cultural anthropology doctoral students who were expert readers. Additionally, he interviewed students to determine if students had high prior knowledge related to a text from their own special field and low prior knowledge related to a text from an unfamiliar field (cognitive psychology).

Of the five remaining studies that used flawed assessment techniques, three used familiarity ratings, one used interviews, and one used a sorting task. The sorting task was used by Byrnes and Guthrie (1992) to determine the prior conceptual knowledge level of 32 undergraduates. 24 cards had to be sorted on the basis of something they have in common. Each time a subject correctly sorted an organ of its part into one of the 3 specific systems (i.e. digestive,

TABLE 1. *Studies using flaw measures of prior knowledge and reporting positive effects*

Author; date	Subject; n; type	Outcomes	Independent variable	Treatment	Dependent variable
Afflerbach (1986) p/5	5 doctoral chemistry students, and 5 doctoral anthropology students	Readers can use knowledge of text structure and the context domain of the text to assign importance. Readers' PK for a text influenced the goals which readers set and the corresponding levels of importance assignment processes used.	PK, i.e. text familiarity (high, i.e. familiar text vs. low, i.e. unfamiliar text)	Reading each passage aloud and giving verbal reports of the processes used for constructing main idea statements, i.e. performing importance assignment strategies	- Main ideas in verbal reports - strategies used to construct main ideas
Afflerbach (1990) p/2	4 anthropology doctoral students, 4 chemistry doctoral students	Expert readers automatically constructed the main idea significantly more often when reading texts about familiar topics, i.e. when they had PK of the content domain of the text.	- Text familiarity (familiar vs. unfamiliar)	Reading both texts aloud, reporting on the prompts (red dots in text) on strategies using to construct a statement of the main idea	- Occurrences of the main idea construction strategies: draft-and-revision; topic/ comment; automatic; initial hypothesis; listing
Britton & Tesser (1982) p/2	Experiment 1: 46 undergraduates	Experiment 1, 2 & 3: PK that is used in an ongoing cognitive task (reading in exp.1, problem solving in exp.2, thinking in exp.3) occupies capacity in the same limited capacity system that is used to perform the cognitive task.	Experiment 1: - PK (high: reading 2 related pages preceding the target passage vs. low: reading 2 unrelated pages preceding the target passage) - reading time (=time Ss used to read the passages)	Experiment 1: Reading the target passage (=primary task) and meanwhile reacting on clicks (=secondary task).	Experiment 1: - use of cognitive capacity during primary task: measuring performance decrements on secondary task (=reaction time to clicks)
2	Experiment 2: 24 undergraduates as chess novices, 7 undergraduates and 9 members of the chess club as chess experts.		Experiment 2: - PK (novices vs. experts) - thinking time (=time Ss were thinking of the best possible move in chess game, maximum 2 minutes)	Experiment 2: Processing a series of chess middle game positions and figuring out the best possible move (=primary task) and meanwhile reacting to clicks (=secondary task).	Experiment 2: - use of cognitive capacity during primary task: measuring performance decrements on secondary task (=reaction time to clicks)
2	Experiment 3: 48 undergraduates		Experiment 3: - PK (strong vs. weak schema) - condition (universal vs. specific schema condition) - thinking time (=time Ss were thinking during treatment, maximum 30 seconds)	Experiment 3: Universal condition: reading descriptive attributes (=primary task), and thinking of an individual or a group and meanwhile reacting to clicks (=secondary task). Specific schema condition: viewing of videotapes and thinking of quality of play and fashion (=primary task), and meanwhile reacting to clicks (=secondary task).	Experiment 3: - use of cognitive capacity during primary task: measuring performance decrements on secondary task (=reaction time to clicks)
Byrnes & Guthrie (1992) p/2	32 undergraduates (M= 24;3 years)	Conceptual knowledge facilitated textbook search only when Ss were given the standard text	- Prior conceptual knowledge level (high vs. low) - text structure (standard vs. non-standard)	Reading the text and finding the answers to two questions	- Total time to correct answer - number of chapters searched - number of times Table of Contents was consulted (TC consult)

TABLE 1, cont. *Studies using flaw measures of prior knowledge and reporting positive effects*

Chiang & Dunkel (1992) p/2	360 EFL (English as a foreign language) male undergraduates	PK has a significant impact on EFL listeners' memory for information contained in the passage-independent test items.	- Listening proficiency (high [HILP] vs. low [LILP]) - PK (familiar vs. unfamiliar topic) - test type (passage-independant vs. passage-dependant items) - speech modification (redundant vs. nonredundant speech)	Listening to a lecture on a familiar or unfamiliar topic, with redundant or nonredundant speech	- A 30-item mc comprehension test per topic; 15 items per test type
Clifton & Slowiaczek (1981) p/2	Experiment 1&2: 32 undergraduates	Experiment 1&2: Experimental Ss who learned new facts about famous people in the context of a story seemed to organize the new information with old knowledge in an orderly fashion. Ss verified inferences faster when the new facts were already related to old knowledge than when they were not.	Experiment 1&2: - relatedness (statement related vs. unrelated with PK about famous people) - training condition (statements listed vs. statements in short biography) - probe type in verification posttest (name of famous person vs. description of famous person)	Experiment 1&2: studying the lists or biographies, followed by a training drill	Experiment 1&2: - average reaction time on verification test, 4 blocks of 24 sentences - total number of errors on verification test - inference time on verification test (= reaction time on descriptions as probe type minus reaction time on names as probe type)
2	Experiment 3: 48 undergraduates	Experiment 3: Ss verified inferences rapidly when the old and new facts combined in the inference were related to the same perspective about the famous person; they were not fast when the facts were related to different perspectives.	Experiment 3; - training condition (statements listed vs. statements in short biography) - probe type in verification posttest (name of famous person vs. thematically consistent description of the famous person vs. thematically inconsistent descriptions vs. consistent inference time vs. inconsistent inference time)	Experiment 3: studying the lists or biographies, followed by a training drill	Experiment 3: - average reaction time on verification test, 8 blocks of 14 sentences - total number of errors on verification test - inference time on verification test (= reaction time on descriptions as probe type, minus reaction time on names as probe type)
Johnston & Pearson (1982) r/2,3	130 eight graders	Background knowledge (=text familiarity) has a biasing effect on comprehension tests. More substantial background knowledge would allow the reader to construct a framework with which to 'anchor' further information. Students with less background knowledge performed worse than students with greater background knowledge.	- Connectives in text (implicit vs. explicit) - text familiarity (familiar vs. unfamiliar text)	Reading the text	- Correct answers on 41-item mc test per text (comprehension), - of which 8 background kn. items (background knowledge)
Lavoie (1989) r/5	14 biology I and II high school students (15-18 years)	Successful predictors generally had high initial knowledge of the subject matter and were formal. Unsuccessful predictors generally had low initial knowledge and were concrete. High initial knowledge seemed to be more important to predictive success than stage of Piagetian development. Motivation and persistence affect the behaviors responsible for prediction of problem-solving success.	- Cognitive development in Piagetian interview (concrete operational vs. formal operational) - initial subject matter knowledge (high vs. moderate vs. low)	A prediction thinking-aloud interview on water pollution, involving written material and a computer simulation program	- Number of occurrences of behaviors for program exploration and prediction

TABLE 1, cont. *Studies using flaw measures of prior knowledge and reporting positive effects*

Mathews (1982) o/2	30 fourth graders	Different (not merely more) information was accessible to the PK and the unrelated knowledge group, and more information was available to the PK group.	- Passage (related (=PK group) vs. unrelated (=unrelated knowledge group) to the target passage)	Hearing the target passage	- Number propositions in free recall (P) - levels in the hierarchy of propositions - logical relations between propositions - number of correct answers on probe questions (Q) - difference between P and Q (Q-P)
Willoughby, Waller, Wood & MacKinnon (1993) p/2	100 undergraduates (M=19;5 years)	The interaction between PK and strategy instruction offers a strong support for the knowledge base interpretation of elaborative interrogation's potency. It is not active learning per se that is responsible for elaborative interrogation benefits, but the making of connections to PK.	- Condition (elaborative interrogation (=reading and answering why-questions) vs. repetition control (=reading aloud) vs. no-exposure control (=no reading)) - format (facts presented according to topic vs. fact presented according to animal) - PK (high: familiar animals vs. low: unfamiliar animals) - time of test (posttest vs. follow-up test)	Reading the statements using the elaborative interrogation or the repetition control strategy.	- Score on immediate memory posttest; matching facts with animals - score on delayed memory follow-up test (same as immediate test), 4 weeks later
Willoughby, Wood & Kahn (1994) p/2	Experiment 1: 96 introductory psychology students (M=20;9 years)	Experiment 1, 2 & 3: Elaborative interrogation was most effective when learners were able to draw on a rich knowledge base. When the knowledge base was low, imagery-based strategies were more potent then elaborative interrogation.	Experiment 1: - familiarity (familiar vs. unfamiliar animals in stories) - study condition (elaborative interrogation vs. imagery vs. repetition control) - pictures (pictures vs, no pictures presented with the stories)	Experiment 1: reading the 60 facts about the animals	Experiment 1: - score on 60-item matching test (matching facts with animals)
2	Experiment 2: 68 undergraduates (M=21 years)		Experiment 2: - study condition (elaborative interrogation vs. repetition control) - background knowledge (high vs. low)	Experiment 2: reading the 40 facts about the islands	Experiment 2: - score on 40-item matching test

TABLE 2.

Author; date	Domain; course	Measurement of prior knowledge (PK)
Afflerbach (1986) p/5	2 passages; 1 about chemistry (590 words), 1 about anthropology (596 words)	PK: an interview to determine if Ss had high PK for text from their field of study, and low PK for the text from the unfamiliar field
Afflerbach (1990) p/2	A text about anthropology (596 words) and a text about chemistry (590 words)	PK: No assessment of PK. Text familiarity was controlled by having students read texts about their study-subject or not about their study-subject.
Britton & Tesser (1982) p/2	Experiment 1: selections from novels (300 to 450 words)	Experiment 1: PK: no assessment of PK. PK was controlled by letting Ss read either 2 related (high PK) or unrelated pages (low PK) preceding the target passage.
2	Experiment 2: a series of chess middle game positions	Experiment 2: PK: no assessment of PK. Chess novices and experts were selected based on their answers to questions about how many times they played chess and about whether or not playing in tournaments.
2	Experiment 3: index cards with 4 attributes descriptive of individual's personality for the universal schemata condition (based on notion that all people either have a strong or weak schema about a topic), and videotapes of football and fashion for the specific schema condition (some people have a strong schema and others a weak for the same topic)	Experiment 3: PK: no assessment of PK. It was assumed that Ss have a strong schema for thinking about the personality of an individual, and a weak schema for thinking about the 'personality' of a group. Also, males were assumed to have a strong schema for football and a weak for fashion. For women, vice versa. This assumption was tested with questionnaire data.
Byrnes & Guthrie (1992) p/2	Two texts describing anatomical parts; one conventionally grouping organs (standard) and one non-conventionally (non-standard)	PK: a sorting task to determine prior conceptual knowledge level

excretory or circulatory), they were awarded points. The authors found that high prior knowledge students performed significantly better on all dependent variables when using the standard version of the text (i.e., a traditionally grouped description of anatomical parts). For our analysis, it is important to note that the dependent variables in this study were aspects of search strategy (time used, number of chapters searches, number of times that content table was consulted).

Studies by Clifton and Slowiaczek (1981) and Willoughby, Waller, Wood, and MacKinnon (1993) used measures of familiarity to assess prior knowledge. In the Clifton and Slowiaczek (1981) studies, familiarity with famous people was assessed, while in the latter study subjects selected animals that were familiar (e.g. the house mouse) or unfamiliar (e.g. the chickaree). The dependent variables in these studies were process variables, such as average reaction time and inference time. The results indicated that subjects with prior knowledge

TABLE 2, cont.

Chiang & Dunkel (1992) p/2	A text on Amish People (650 words) (unfamiliar text) and a text on Confucius (680 words) (familiar text)	PK: no assessment of PK. PK was controlled by assigning students to either a lecture on a familiar or an unfamiliar topic.
Clifton & Slowiaczek (1981) p/2	Experiment 1&2: 48 statements about famous people	Experiment 1&2: PK: no assessment of PK. Normative studies were administered to assess familiarity, relatedness and appropriateness of the statements.
2	Experiment 3: 28 statements about famous people	Experiment 3: PK: no assessment of PK. Normative studies were administered to assess familiarity, relatedness and appropriateness of the statements.
Johnston & Pearson (1982) i/2,3	6 texts (600 words) on the Civil War, manipulated by removing the connectives, and changing the setting in order to reduce background knowledge (text familiarity)	PK: no assessment of PK. PK was Experimentally manipulated by giving students either a familiar or an unfamiliar text.
Lavoie (1989) i/5	A prediction thinking-aloud interview on water pollution	PK: preliminary questions on water pollution
Mathews (1982) o/2	Text fragments that were related or unrelated to PK	PK: 15 Ss received PK and 15 Ss received unrelated knowledge
Willoughby, Waller, Wood & MacKinnon (1993) p/2	4 sets of stimulus materials, each consisting of 10 stories. Each story is composed of 6 statements describing animal attributes.	PK: no assessment of PK. Selection of animals described in the stories was based on indications of 40 different students.
Willoughby, Wood & Kahn (1994) p/2	Experiment 1: 10 stories with 6 facts each, describing animals	Experiment 1: PK: no assessment of PK. PK was controlled by describing either familiar or unfamiliar animals
2	Experiment 2: 40 facts about islands taken from a fantasy book series	Experiment 2: PK: no assessment of PK. PK was controlled by selecting students that had either studied the first book of the series or not studied this book.

organize new knowledge in an orderly manner, verify inferences faster, and profit more from elaborative interrogation. Again, these findings do not provide evidence for the impact of prior knowledge as much as they explain the nature of such effects. Clearly, support can be found in these studies for the accessibility hypothesis (prior knowledge increases accessibility of knowledge and reduces the load on the working memory is reduced) and the retrieval-aid hypothesis (connections between existing knowledge increase retrieval) (Dochy, 1992).

Lavoie (1989) used 'thinking-aloud' interviews in his study to find out what students knew about water pollution. The interview information combined with students' GPA (Grade Point Average) and CTBS (Comprehensive Test of Basic Skills) results of math and science was used to deduce the initial knowledge levels of 14 students. The students then used a computer simulation of water pollution to predict the effects of the independent variables on the dependent

variables over a period of time. Lavoie found that successful predictors generally had high initial knowledge. From our perspective, it is important that the author used a thorough combination of methods and sources to calculate students' initial knowledge levels. Thus, we cannot speak of a 'flawed' method.

Overall, we conclude that only four studies used weak assessment methods. However, none of these studies clearly investigated the impact of prior knowledge on performance. Even so, it does not appear that the use of flawed methods would mask such positive findings. These last studies demonstrate that when appropriately applied such assessment methods can be useful for investigating why prior knowledge has such positive effects on the learning process.

Mediating variables and the positive effect of prior knowledge. The remainder of the studies we reviewed indicated that prior knowledge had a positive effect on performance and employed what we considered to be sound and valid forms of assessment (e.g., multiple-choice, open-ended, and completion questions). However, we would like to highlight a few studies, which found such positive effects.

Figure 1, the characterization of prior knowledge we used to guide this review, makes a clear distinction between the direct and indirect effects of prior knowledge. Many effects reported in the studies are considered to be direct effects. However, it is possible that some of these effects are in fact indirect effects, but the design of the studies makes it impossible to detect these indirect effects. Minnaert and Janssen (1992, 1995), for example, distinguish between the direct and indirect effects. They found that while prior knowledge directly effects study success and progress, it also has an indirect effect via the speed and accuracy of study behavior. This supports Dochy's (1992) belief that prior knowledge effects performance through the use of learning time. While some researchers define time as the period needed to react or give an answer in the posttest session (e.g., Clifton & Slowiaczek, 1981), others have shown (Birkmire, 1985; Morrow, Leirer, & Altieri, 1992) that the rate at which information is read from text depends upon the reader's knowledge of the topic.

Additionally, Birkmire found that reading time is effected by the logical position of the information in the text structure. Experimenters concerned with the relation between prior knowledge and the hierarchical structure of information in texts have shown that high knowledge individuals generally recall more information from text that has structured content (Alexander et al., 1990; Chiesi et al., 1979; Langer, 1984). This relation between prior knowledge and text structure can be seen as a second indirect effect of prior knowledge. On the other hand, the structure of a text may also be associated with the clarity of learning materials. Byrnes and Guthrie (1992) found this to be true when they examined the benefits of prior conceptual knowledge on locating specific information in a text. McKeown, Beck, Sinatra, and Loxterman (1992) also demonstrated that students were better able to utilize prior knowledge if the text was coherent enough to connections to be made between the text information and their prior knowledge.

Examination of statistically significant interactions between prior knowledge and other variables reported in the studies also reveals that interest is a variable influencing the relationship between prior knowledge and performance. However, the literature is inconclusive about the nature of this relationship. Alexander

et al. (1990) concluded that the difference in learning between low and high knowledge individuals is lessened when interestingness of the learning material becomes higher. Henk, Stahl, and Melnick (1990), one the other hand, argue that the interrelationship between prior knowledge and level of involvement with the topic is more complex. Garner and Gillingham (1992) also offer a different view, concluding that while individuals with low and high prior knowledge are more likely to be uninterested, individuals with moderate prior knowledge are more likely to be interested. Thus, while the relationship between prior knowledge important, who benefits most is unclear.

Our examination also indicates that metacognitive knowledge is an important factor with respect to the influence of prior knowledge. Path analyses done by Hasselhorn and Körkel (1986), and Körkel and Schneider (1989) reveal that knowledge monitoring, strategy regulation, and procedural metacognitive knowledge are mediating variables. Studies have also identified learning strategy as a specific learning strategy as a specific variable influencing the relationship between learners' prior knowledge and their performance (e.g., Afflerbach, 1986; Chan et al., 1992; Martens, Valcke, & Potier, 1997; Prosser, 1987). However, these studies are not in agreement about how learning strategies are related to prior knowledge. Alexander et al. (1989), Gaultney (1995), and Prosser (1987), for example, find that a particular amount of prior knowledge is necessary to acquire certain learning strategies. Other experimenters find that highly knowledgeable individuals use different learning strategies than individuals with low prior knowledge (Afflerbach, 1986; Lambiotte & Dansereau, 1992; Spires, Donley, & Penrose, 1990; Tennyson & Bagley, 1991; Willoughby et al., 1994).

Similar effects are detected when we look at interactions between prior knowledge and other variables. Various studies report statistically significant interactions between prior knowledge and instructional methods, indicating that individuals with varying levels of prior knowledge benefit from diverse learning or instructional strategies (e.g., Lambiotte & Dansereau, 1992; Pascarella, 1978; Phye, 1994; Sanbonmatsu, Kardes, & Herr, 1992). Many experimenters also report significant interactions between prior knowledge and content and structure of the materials to be learned (e.g., Alvermann et al., 1985; Birkmire, 1985; Byrnes & Guthrie, 1992; Chiesi et al., 1979, Fincher-Kiefer, Post, Greene, & Voss, 1988).

Prior Knowledge and Progress Assessment

Before concluding we also wish to address studies which assessed prior knowledge during the learning process, often referred to as progress assessment or assessment of growth studies (Dochy, 1996a; Moerkerke, 1996). We choose to separate these studies out from the others because progress assessment can be seen as a form of repeated prior knowledge assessment (e.g. between each subsequent module) (Moerkerke, 1996). In our search, we reviewed 11 publications dealing with progress assessment. The majority of these studies indicated positive effects of assessment on performance but a few did suggest that negative or no effects assessment on performance.

For example, progress assessment was found not to affect performance in a study by Dyck, Van de Looverbosch, and Wouters (1982). While their self-evaluation progress tests did not have an effect on students' examination scores,

students' attitude toward this formative self-evaluation was very positive. The one study (Tan, 1992) that suggests the negative effects of progress assessment used frequent summative assessment to examine students' learning. It was believed that students adopted a surface reproductive approach aimed at passing the exams rather than at understanding the subject matter. The use of summative evaluation procedures, however, is controversial. The purpose of such an evaluation is to certify and value students' performance, not to diagnose learning deficiencies or provide clues for remedial education. In a comparative study, Schloss, Smith, and Posluzsny (1990) found students' performance on objective tests using formative evaluation was significantly better than their performance following instruction utilizing summative evaluation. In another study, Waugh (1985) found that there was a distinction between the effects of assessment on immediate and continued performance. Specifically, diagnostic testing positively influenced immediate performance but not continued performance. Carswell, Primavesi, and Ward (1987) identified continuous assessment as a significant predictor of student failure on the final examination.

Most of the progress assessment studies, however, indicated that progress assessment increased student performance (e.g., Chansarkar & Rautroy, 1981; Fuchs, Deno, & Mirkin, 1984; Lan, Bradley, & Parr, 1994). Dassa (1990) also found that individual differences in the performance variables were reduced for the students receiving diagnostic tests, as opposed to students not receiving diagnostic tests. Additionally, a study combining prior knowledge and progress assessment indicated that learning process variables such as metacognitive ability are important in shaping students' progress in their first year of college. In turn, performance in the first year, as a measure of progress, was the most powerful predictor of future performance at the university (Murray-Harvey & Keeves, 1994).

The reasons for the effects of progress assessment on performance is not clear in the literature. When Sevcik et al. (1983) conducted a study on the effects of a direct and frequent measurement and evaluation system on students' knowledge of their performance he found that this form of assessment provided teachers with a more realistic estimate of students' progress. In their work, Brecht and Glass (1968) have also hypothesized that the use of pretesting and frequent assessment may alert students to what they need to gain from the instruction. A study by Welch and Walberg (1970), however, disputes this hypothesis. Despite these inconsistencies, the studies we have discussed here do provide further evidence that the form of assessment can affect student performance.

Conclusions

The purpose of this review was twofold. First, we wanted to overview research related to effects of prior knowledge on performance. Second, and perhaps more importantly, we wanted to examine the effects of prior knowledge in relation to the methods of assessment used in classroom and educational environments. We were primarily interested in empirical, classroom based studies with a clear description of the conditions and measures used to assess the effects of prior knowledge on learning. As a result, our search for work examining the role of prior knowledge on performance yielded 183 studies, overviewed in the previ-

ous section.

Before discussing the conclusions we can draw from these studies, however, it is important to consider the limitations of this review. First, the selection of studies for a review of any type is subject to selection bias. Bias, for example, can be caused by selecting only published work, which tends to report only statistical significant results (Glass, 1976). We attempted to avoid this form of bias by including unpublished work and studies finding no effects. However, it is notable that authors who observed no effect of prior knowledge attributed this finding to an inaccuracy in their study or inaccuracies in subjects prior knowledge. Second, the search of the literature was restricted by using specific keywords to search the various indices for a limited time frame. Given the longstanding interest in prior knowledge and the wide range of terminology used to refer to prior knowledge, some relevant studies may not have been included. Finally, given the nature of the narrative review, it is also possible that our own views may have colored our interpretations of the literature, despite our efforts to remain objective.

Despite these limitations, we feel that several useful conclusions may be drawn from the studies discussed in this review. While some of these conclusions have been discussed elsewhere, we feel that it is useful to provide a brief discussion of them here as well.

There is a strong relationship between prior knowledge and performance. The majority of the studies we reviewed (91.5%) reported positive effects of prior knowledge on performance. Further, the importance of prior knowledge in learning was demonstrated by studies finding that prior knowledge generally explains between 30 and 60 % of the variance in performance. Investigations using causal modeling techniques also support the importance of prior knowledge. Most studies tended to consider the direct effects of prior knowledge. However, it is essential not to overlook the indirect effects of prior knowledge through the clarity of study materials, the use of learning time, as well as prior educational performance. This leads us to our second conclusion.

Other learning variables, related to prior knowledge, are essential for student performance. It would be foolhardy to conclude that learning is completely directed by a learner's preexisting knowledge base. While the literature often stresses the impact of prior knowledge to the extent that all learning might depend on it (Resnick, 1981), other student characteristics influence the learning process, and interact with the effect of prior knowledge.

Authors have argued that interaction between cognition and metacognition demands that they be encompassed in one model of prior knowledge (Dochy & Alexander, 1995). However, while the work of Voss, Blais, Means, Greene, and Ahwesh (1986) and Alexander et al., (1989) has provided illustrations of this interactivity, metacognition and content knowledge are generally not examined in the same studies. Despite this limitation, learning strategy and procedural metacognitive knowledge appear to be mediating variables essential for learning. Learning strategy, for example, is a variable influencing the relationship between learners' prior knowledge and the outcomes, but the relationship remains unclear.

Interest is a variable influencing the relationship between prior knowledge and measures of achievement, although this interrelationship is complex. In an

earlier investigation among adult students, we have argued that interest and beliefs can be critical to human development (Alexander & Dochy, 1995). Also, accessibility, availability, and the structure of prior knowledge are factors of importance, influencing the relationship between prior knowledge and achievement.

Method of assessment influences the observed effect of prior knowledge on performance. Our search of the literature supported the finding by Dochy and Alexander (1995) that studies use many different concepts and measurement instruments. While this could be regarded as a handicap in comparing studies, it is also advantageous for examining how prior knowledge, assessed with different measures, influences educational performance in different situations (Dochy, Alexander, & Moerkerke, 1995). The studies presented in this review suggest that the positive effects of prior knowledge are most apparent when objective methods are employed.

Examination of the studies leading to no or negative results of prior knowledge on performance reveals that some conditions can foster these results. As previously discussed, the assessment method is of grave importance. Superficial methods such as familiarity ratings fail to show a clear relationship between prior knowledge and learning outcomes. Thus, in designing studies, how to assess prior knowledge is an issue in need of careful consideration. While familiarity ratings, experimenter assumption, or self-estimation may be less costly and easier to implement, they may not provide an adequate measure of prior knowledge. Flawed assessment methods cannot be used as a reliable source of feedback to the students and as a source of information for curriculum design. However, such measures might give insight into other student characteristics that may interact with prior knowledge. For example, measurement by means of self-estimation can give information on students' capabilities of critical self-reflection.

Further, misconceptions and inconsistent information tend to hinder the influence of prior knowledge. This underscores the need to assess not only the amount of the student's prior knowledge, but also to take into account the accessibility, availability and structure of the prior knowledge as measured. Such an assessment gives a more complete picture of individuals' knowledge and perhaps insight into their behavior.

Flawed assessment methods can yield informative results. While there was a relationship between the use of flawed methods and finding no or negative effects of prior knowledge, several studies using such methods reported a positive effect. Closer examination of these studies revealed that such flawed assessment methods can be useful for exploring learning processes in order to find explanations for the effect of prior knowledge. This is particularly true when they are combined with other forms of knowledge assessment.

The studies using flawed assessment methods reveal some interesting findings: for subjects having little of no prior knowledge on a topic, the level of interest plays a more important role; one should no subsume that activating prior knowledge leads to the availability of prior knowledge for learning; the findings do not hold for situations where the knowledge is unreal of simulated, facts should be actual with real implications; it is better having no prior knowledge that wrong prior knowledge because learning from texts not easily over-

rides prior knowledge; and investigating knowledge gain is detrimental to high knowledge individuals.

Thus, the use of familiarity ratings, self-estimation, and matching tests should not be abandoned, but carefully considered in light of the study's objectives and the other measures to be implemented.

Further Research and Educational Implications

In this review, we focused on the effects of prior knowledge on performance related to the method of prior knowledge assessment. Our results suggest that assessment is an issue, which must be considered. However, while our results also demonstrated the benefits of prior knowledge on performance, it is still unclear which cognitive process or processes are responsible for this. Pressley and McCormick (1995) have discussed the effects of prior knowledge on learning processes, addressing four specific effects on learning: (a) knowledge-base meditation can replace use of strategies; (b) prior knowledge can enable use of strategies; (c) knowledge-base meditation and strategy use can make unique contributions to learning; (d) knowledge-base activation strategies can interfere with new learning. On the basis of experimental research (see Dochy, 1992 for a complete overview), other researchers also advanced a number of explanatory theories (e.g., restructuring theory, accessibility theory, selective attention hypothesis, retrieval-aid theory, and elaboration theory). These different theories are not necessarily mutually exclusive. Instead, they are all concerned with the progression of phases during information processing. Accordingly, prior knowledge is believed to influence each of these phases. That is, the different theories or approaches recognize the positive influence of prior knowledge on the selection process from the knowledge base, the capacity of working memory, the elaborations carried out on new information, the storage of new information in long-term memory, and the retrieval of new information. However, more concrete investigations on these processes in classroom settings could lead to the formulating of concrete guidelines to organize learning environments in an effective way, taking prior knowledge differences between students into account.

Further research is therefore necessary to understand the facilitating effect of prior knowledge in educational situations where performance return and improvement of quality are the objectives.

In our analysis, we also took a detailed look at studies finding no or negative effects. Future educational research may wish to investigate how such effects originate.

From this review, we can conclude that prior knowledge is indeed an effective aid for learning new knowledge. This result supports the current practice of activating prior knowledge at the beginning of a learning process. Such practice is very explicit in the applications of powerful learning environments based on constructivism (De Corte, 1990). In problem based learning and the problem method, for example, activating prior knowledge is an explicit phase. The students' reflection on their prior knowledge is facilitating learning. Likewise, students' reflection on what knowledge is important for the learning process probably enhances learning. This phenomenon of sensitizing students by means

of pretests was discussed by Welch and Walberg (1970). Further research on this sensitizing effect of assessing prior knowledge would be worth repeating from the point of view of the different assessment methods. Moreover, it has also been shown that prior knowledge is a good predictor of problem solving (Lavoie, 1989; Segers, 1996). Thus, future studies could focus on knowledge acquisition and the acquisition of problem-solving skills.

Finally, as we continue to explore how prior knowledge influences the learner it is essential that particular attention be given to the assessment of prior knowledge. Only by doing so can a more accurate representation of an individual's knowledge be attained, thereby enhancing our ability to unravel the complexities of learning.

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