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ABSTRACT

The structure of expertise is investigated along a variety of dimensions. A new and distinct approach is used, which is based on extensive analysis of theories, models, and practice-based strategies found in the literature. This base is used to define a set of dimensions that might be helpful in constructing knowledge profiles. The four dimensions designated are: (1) cognitive-psychological; (2) educational-psychological; (3) psychometric; and (4) content-based. Two approaches are used to support the relevance and validity of the knowledge profile dimensions, both based on data from a research project involving 627 students at the University of Maastricht and the Dutch Open University. The extent to which variables along the dimensions give information about different components of expertise was examined, and the discriminatory power of the knowledge profile dimensions to make apparent expertise differences between student subpopulations was explored. The nonhierarchical dimensions identified suggest that they do relate to different components of the prior knowledge state, a finding further supported by the profile analyses of the different populations. Several knowledge profile dimensions seem promising for differentiating prior knowledge. Eight figures and 13 tables present analyses data. (Contains 38 references.) (SLD)

Onderwijstechnologisch innovatie centrum OTIC

Validation of knowledge profile dimensions:

Looking for empirical evidence

F.J.R.C. Dochy

M.M.A. Valcke

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- the developments of the "Computer Assisted Testing"-project;
- the developments of "Adaptive Testing" and the IRT-applications (Item-Responds Theory); and
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Centre for Educational Technology and Innovation
Open University

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1. Introduction

In earlier research on domain-specific expertise, we focused on the structure of prior knowledge along the content dimension. A series of investigations was conducted within the field of 'economics'. For an overview, we refer to Dochy (1992). In this report we investigate the structure of expertise along a variety of dimensions.
Our discussion in relation to the structure of expertise introduces a new approach towards the structure-of-knowledge problem. In the theoretical part of this text, we discuss this new and distinct approach which is based on extensive analysis of theories, models and practice-based strategies found in literature. This base is used to define a set of 'dimensions' that might be helpful to construct 'knowledge profiles'. Four types of dimensions are designated : cognitive-psychological dimensions, educational-psychological dimensions, psychometrical dimensions and content-based dimensions.

We provide data to support the relevance and validity of the knowledge profile dimensions. Two approaches will be adopted, based on data gathered during a research project involving a sample of university students. First, an analysis of the extent to which the variables along the dimensions give information about different components of expertise. Second, an analysis of the discriminatory power of the knowledge profile dimensions to make apparent expertise differences between a variety of student sub-populations.
In part 7 and 8 of this report, the first approach is adopted, whereas in part 9, the profile dimensions are used to compare a variety of student-populations. In view of the first approach, a distinction is made between hierarchical and non-hierarchical dimensions.

2. Expertise and the 'structure of knowledge'

The quality and impact of expertise has been a major issue in our research about the role of prior knowledge at university level (Dochy 1988a en 1988b; Dochy & Steenbakkers, 1988; Dochy & Bouwens, 1990; Dochy, Bouwens, Wagemans & Niestadt, 1991; Dochy, 1992). An important conclusion from this research body indicates that it looks promising to analyze in more detail the complex of components of expertise. A first and promising attempt in this direction focused on the structure of expertise along the content dimension (Dochy, Valcke & Wagemans, 1991; Wagemans, Valcke & Dochy, 1991). As is argumented in Dochy (1992), 'expertise' will be used here as a synonym of 'prior knowledge state'.
Three important concepts are presented in the former paragraph : expertise, components of expertise and a complex of components. These three concepts refer to the value attached to the specific "structure" of expertise. Our earlier research revealed that such a structure could be indicated in prior knowledge, e.g. along the content dimension. We did for instance discriminate between Optimal Requisite Prior Knowledge and Mathematics Knowledge. But it was also suggested that the differentiation of components of expertise along other dimensions is needed to be helpful to diagnose and support educational practice (Dochy, Valcke & Wagemans, 1991; Wagemans, Valcke & Dochy, 1991).

3. The structure of knowledge: a central issue in educational sciences

The structure of knowledge issue has been dealt with by a variety of theoretical disciplines : cognitive psychology, educational psychology, artificial intelligence, etc. From a pragmatic point of view, the issue has also been of prime importance in applied sciences like instructional psychology, curriculum development theories and psychometry.

Theoretical disciplines like cognitive psychology, educational psychology, artificial intelligence, etc. have - from their points of view - highlighted the "structure of knowledge" resulting in a puzzling variety of approaches, focuses, models, theories, research attempts, ... A representative sample of authors comprises e.g. Ausubel (1968), de Groot (1946), Mayer (1979), Reigeluth & Stein (1983). We give a short outline of some of their specific theoretical contributions :

- An early, cognitive-theoretical approach appears in the work of Ausubel (1968) who argues that new knowledge is only acquired to the extent that it is meaningfully related to existing knowledge. Ausubel maintains that knowledge is organized primarily in a hierarchical fashion, which implies that mastery of higher knowledge levels assumes mastery of all lower knowledge levels. Additionally, Ausubel advances that the various pieces of information integrated within a particular knowledge structure are highly interrelated. Thus, the more structured prior knowledge, the more flexible and easy the acquisition of new knowledge becomes.
- Ausubel's conceptualization of learning as the assimilation into prior knowledge, is echoed and extended in Mayer's (1979) schema theory. New knowledge is - according to Mayer - assimilated into a hierarchy of progressively more specific content within the learner's cognitive store. Thus, the basic learning process can be described as the assimilation of new knowledge within hierarchically ordered schemata.
- Another benchmark is set by the "Elaboration theory". According to this theory, multiple access avenues become available to the learner by the activation of alternate relational paths . This is also explained by the assumption that knowledge acquisition is facilitated to the extent that information is organized in a hierarchically integrated mode (Reigeluth and Stein, 1983).

These theories are important since they stress the "structured" and hierarchical nature of knowledge, but they lack empirical support to ground their validity (Reigeluth and Stein, 1983). Additional support, especially for the hierarchical nature of the knowledge organization should be searched for.

From a rather pragmatic, e.g. instructional-psychological, point of view the structure-of-knowledge paradigm should also be investigated in further detail in order to find more efficient ways for using instructional technology. Our attempts to find ways to manage prior knowledge indicate e.g. that different components of expertise should be taken into account (e.g. along the content dimension) and that components of expertise along other dimensions could be helpful to support and diagnose in educational settings.

If we summarize the variety of theoretical and pragmatic approaches, four main types of dimensions to structure knowledge can be conceptualized :

Content related dimensions
Educational dimensions
Epistemological dimensions
Item characteristic dimensions

In the next parts of this report, these dimensions will be recapitulated and discussed in more detail. But more important is our attempt to reveal some new insight into the hierarchical nature of the structure of knowledge. As indicated earlier this will be the main issue in the empirical part of this text.

It should also be noted that - when putting forward these theories and approaches towards prior knowledge - we adopt an information processing view towards learning (see Sternberg, 1985a & 1985b). This is inspired by our dynamic approach towards knowledge acquisition; a departure which is also advocated by information processing theory.

4. Towards a new key concept : knowledge profiles

As such, the concept of 'knowledge profiles' is not found in literature. Only 'student profiles' (Wolf, et. al., 1991) and 'cognitive profile' (Letteri, 1980) have some similarity in meaning.

Our use of the concept 'profile' is derived from the practice, common in educational research, of plotting as a graph (or profile) the raw or standardized scores of a group or individual (Keeves, 1988). In analyzing research data, comparisons are made between persons or groups of persons in terms of a set of measurements about related aspects. For each person or group a profile can be obtained by combining the results of the set of parameters. The comparison between individual profiles is known by the generic term 'profile analysis'. Consequently, the concept 'knowledge profile' is used when achievement scores (e.g. on a prior knowledge test) are analysed following the parameters along a dimension and when the results of this analysis are plotted in a graph.

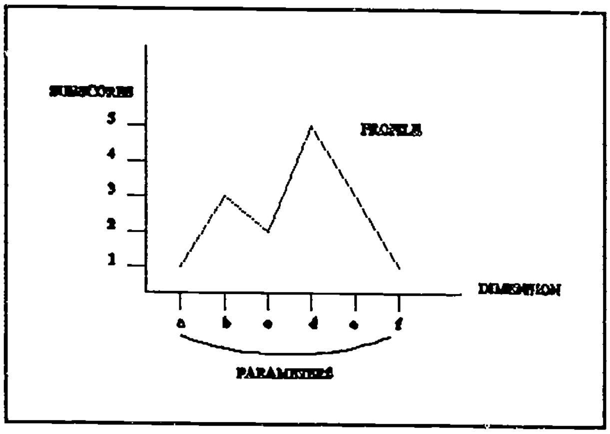

Figure 1: Example of a profile

Figure 1 shows the relationships between some key concepts. A "dimension" is the basis to construct a knowledge profile. Each dimension represents an approach towards the structure of knowledge since it introduces a related set of expertise components. These components are named "parameters".

As suggested above, our concept "knowledge profiles" is related - to a certain degree - to Letteri's use of the concept. His work at the Center for Cognitive Studies, University of Vermont, focuses on the development of an individual's cognitive profile. A profile in Letteri's conception is based on a continuum along which a variety of cognitive dimensions are put one next to the other. Letteri combines up to seven dimensions such as scanning (focus), breadth of categorization and cognitive complexity. An individual's cognitive profile is the diagram, the picture that results after positioning individual scores in relation to each of these dimensions along the continuum (Letteri et. al., 1982).
According to Letteri and Kuntz (1982) very high correlations between an individual's cognitive profile and its performance on intellectual tasks, the ability to learn and school performance have been detected. The results of the Letteri studies are at least amazing. His cognitive profiles can for instance help to separate seventh and eight grade students into significantly different achievement levels; can account for as high as 87 percent of the variance in posttest scores; and predict those scores at a level of .05 or better.
Moreover the results show that a cognitive profile is a basic determinant of academic achievement and can accurately help to identify specific learning deficits that contribute significantly to low academic achievement. Cognitive profiles seem to be reliable predictors of low/high academic achievement (Letteri, 19°0).

Although the Vermont studies provide evidence for the potential of cognitive profiles, some critical remarks are needed.
First, the work at Vermont concentrates rather on 'cognitive styles' and 'characteristics of cognitive

functioning'. This is particularly obvious if we look in more detail to the dimensions used to construct the cognitive profiles. So there is a clear distinction between their and our approach. Our knowledge profile dimensions clearly consist of parameters referring to structure-aspects of knowledge. Second, the Letteri profiles seem not to be appropriate for adult learners because they are based on theories and research concerning child development.
Third, we perceive profiles as diagrams based on a single dimension along which the parameters are clearly interrelated. The use of a set of such dimensions results in the construction of multiple knowledge profiles (i.e. one for each dimension). Letteri constructs only one profile, based on a variety of dimensions. His major focus is on the correlation between this profile and school performance. As a consequence, the remedial power of his profiles remains restricted. The Letteri profile is therefore to be considered as an instrument to differentiate groups performing below or above average, taking into account the perceived correlations between the relative positioning on the profile and external measures of school performance. His remedial method is thus not based on the specific overall profile structure but on related external measures of school performance.
In contrast, our multi-profile approach generates "profile analysis", an application of multivariate analysis of variance (MANOVA) in which several dependent variables are measured on the same scale (Tabachnick & Fidell, 1989). This profile analysis can provide relevant information with diagnostic and remedial value. In this way, the profiles help us to identify learning deficits to be remediated.

5. Overview of the theoretical dimensions

In this paragraph, we review a representative sample of dimensions and parameters currently found in literature. Each of these dimensions is based on a specific model or theory of knowledge structuring, which will only be discussed in short. Literature references are supplied to document the reader, looking for more information. As suggested in part 3 of this text, the "structure of knowledge" issue has been dealt with from a large variety of viewpoints, resulting in a quartet of dimensions.
A first group of dimensions is classified according to common models of the economics domain. Other sets of dimensions are based on theories of knowledge representation, knowledge structure, learning theories, text representation models and psychometric theory.
A first question in relation to each dimension is whether they are applicable as structures to find components of expertise. Secondly - and this will be discussed in the empirical part of this text - are these dimensions useful to differentiate groups of students. In this way we can scrutinize the descriptive, explanatory and remedial prospect of our knowledge profiles.

5.1 Content Dimensions

5.1.1 Economics Subdomains Dimension

Content is one of the most exercised dimensions in order to categorize domain knowledge. Classification based on the parameter 'subdomain' means that the domain of economics will be divided in regular subject matters within the science of economics. One possibility, as implemented in the curriculum of the University of Maastricht, contains nine parameters.

1. Reporting
2. Financing
3. Organization
4. Marketing
5. Macroeconomics
6. Microeconomics
7. Public finances
8. International economic affairs
9. Behavioural and social sciences

5.1.2 Curriculum Dimension

Some parts of the content of a science are supposed to be mastered by the students at certain moments during their study. These moments are called the curriculum levels (first and second year). A team of economists have helped to define these levels. These curriculum levels are subsequent, but too broad to be supposed hierarchical.

1. First year level
2. Second year level

5.1.3 Curriculum Accent Dimension

Within economics it is common to differentiate between two main streams, representing a different accent, i.e. general economics and business administration on the one hand and quantitative economics on the other hand.

1. General economics and business administration
2. Quantitative economics

5.2 Cognitive Psychological Dimensions

5.2.1 Propositional Dimension

Knowledge representation as used in schema theories (Dochy & Bouwens, 1990) takes certain propositions or nodes as a starting point. A proposition is the smallest unit that can be qualified as true or false. According to most schema theories there are five kinds of nodes: Physical State (PS, statement that refers to an ongoing state in the physical or social world), Physical Event (PE, statement that refers to a state change in the physical or social world), Internal State (IS, statement that refers to an ongoing state of knowledge, attitude, or belief in a character), Internal Event (IE, refers to a state change in knowledge, attitude or belief in a character), Goal (G, statement that refers to an achieved or unachieved state that a person wants) and Style (S, statement that refers to details about the style or manner in which an action or event occurred. Further examples and elaborations of these parameters are given in Dochy and Bouwens (1990). These nodes are used in the representational theory of Graesser (1981) to represent knowledge as a network of labelled statement nodes that are interrelated by directed arcs (see further). As such, the nodes do not have any hierarchical relationship.

1. PS
2. PE
3. IS
4. IE
5. G
6. S

5.2.2 Node Relation Dimension

The "Node Relation Dimension" is based on characteristics of the interrelations between the propositions presented above. Relations between propositions can be classified as node relation or arc parameters: Reason (R, a Goal node is a reason for another Goal node), Initiate (I, a State or Event initiates another Goal node), Consequence (C, a State, Event or Goal node that has the consequence of another State or Event node), Manner (M, an Event or Goal node occurs with some style), Property (P, a person, object or entity has some property that is a State node) (see also Dochy & Bouwens, 1990).
These arc parameters are not of a hierarchical nature. The overview on the next page shows what specific relations between the propositions have been identified.

1. G - G REASON
2. PS - G INITIATE IS - G PE - G IE - G
3. PS - PE CONSEQUENCE IS - PE PE - PE IE - PE G - PE PS - PS IS - PS PE - PS IE - PS G - PS
4. PE - S/G MANNER IE - S/G GE - S/G
5. PS - PS PROPERTY

5.2.3. Cognitive Complexity Dimension

Mc Daniel (1991) proposes five levels of cognitive complexity. These parameters are designed to measure thinking processes by determining the cognitive complexity apparent in written interpretations of complex situations.

Level 1: Unilateral Descriptions
The situation is simplified. It focuses on one idea or argument. Alternatives are not identified. No new information, meaning, or perspectives are brought in. "Good-bad" and "either-or" assertions are made. Appeals to authority or simple rules. Information is simply paraphrased, restated or repeated.

Level 2: Simplistic Alternatives
Simple and obvious conflicts are identified, but the conflicts are not pursued or analyzed. Develops a position by dismissing or ignoring one alternative and supporting the other with assertions and simple explanations rather than through deeper assessment of the situation.

Level 3: Emergent Complexity
More than one possible explanation or perspective is identified. Complexity is established and preserved. New elements are introduced. Supports position through comparisons and simple causal statements.

Level 4: Broad Interpretations
Broad ideas help define and interpret the situation. Ideas within the perspective established are manipulated. There is a clearly recognizable explanatory theme. Ideas are integrated into "subassemblies" each supporting a component of the explanation.

Level 5: Integrated Analysis
The situation is restructured or reconceptualized and the problem is approached from a new point of view. A network of cause-and-effect relationships is constructed. Ideas are Integrated and extrapolated. Arrives at new interpretations by analogy, application of principles and generalizations. An organizing framework is constructed, connections are given and consequences are predicted.

1. Unilateral descriptions 2. Simplistic alternatives 3. Emergent complexity 4. Broad interpretations 5. Integrated analysis

5.3 Educational-Psychological Dimensions

Discussing the first two dimensions of this type, i.e. the behavioral and the content dimension, it is noteworthy to mention Component Display Theory (CDT, Merrill, 1983) which makes use of related concepts. CDT can be described as a set of prescriptive relationships that can be used to guide the design and the development of learning activities. A basic assumption of CDT is that there is more than one type of learning and more than one kind of memory structure. Primary aspects of CDT are objectives, learning activities and tests. According to CDT, all objectives or test items can be classified in cells of a matrix, based on a content and a performance dimension. The CDT content dimension distinguishes 'facts, concepts, principles and procedures'. The CDT performance dimension differentiates 'remember, use and find'. This is also conform to Gagné's tripartite : 'information, skills and strategies'. CDT holds that this performance-content matrix can be considered as a taxonomy, thus suggesting a hierarchical base for the two determining dimensions in the matrix.

5.3.1 Behavioral Dimension

The much used distinction between 'declarative and procedural knowledge' can be further operationalized as 'to know, to understand, and to apply'. These three concepts are considered as equivalent to 'recognition, reproduction and production' (De Corte, et al., 1976). The concepts can also be related to the classification : Appreciation, recognition and reproduction of information (= declarative) or production or applications (interpretative, convergent, divergent or evaluative production) which can be viewed as procedural (Keeves, 1988). The three parameters do also correspond with the basic taxonomic levels proposed by several educationalists such as Bloom, Guilford, De Corte and De Block (see Keeves, 1988). Most researchers agree that these parameters are of a hierarchical nature which has also been supported by empirical evidence (Keeves, 1988). Research suggests also that there is some justification for treating Bloom's lower levels as being taxonomic. This should not be the case for the levels 'synthesis' and 'evaluation'(Madaus, et. al., 1973).

1. Know 2. Understand 3. Apply	1. Recognition, Reproduction 2. Production	1. Appreciation, recognition, and reproduction of information 2. Interpretative convergent, divergent or evaluative production	1. Declarative 2. Procedural

5.3.2 Content Dimension

At the content level we can differentiate five parameters: facts, concepts, relations, structures and methods. This is in accordance with the work of Guilford where he distinguishes several product parameters, and the work of other authors (Keeves, 1988). These parameters are widely accepted as being hierarchical (Keeves, 1988).

1. Facts 2. Concepts 3. Relations 4. Structures 5. Methods

5.3.3 Epistemological Dimension

Based on the levels of knowledge representation of Brachman and Schmolze (1985), five levels can be differentiated along this dimension. These parameters can also be considered as the most appropriate combinations of behaviour- and content parameters, as clarified between brackets : knowledge identification (identifying facts and concepts), knowledge conceptualisation (insight in concepts), epistemological analysis (to know and understand relations and structures), logical analysis (to know and understand methods), implementational analysis (application of methods). These levels are considered as hierarchical since they are a combination of the hierarchical behaviour and content dimension.

1. Knowledge identification
2. Knowledge conceptualisation
3. Epistemological analysis
4. Logical analysis
5. Implementational analysis

5.3.4 Layers of Knowledge Dimension

A difference can be made between: static knowledge (description of concepts and relations), knowledge of different types of inferences, knowledge representing elementary tasks (procedures), and strategic knowledge (Clancey, 1983).
The first layer contains the static knowledge of the domain: domain concepts, relations and complex structures, such as models of processes or devices.
The second layer is the inference layer. In this layer we describe what inferences can be made on the basis of the knowledge in the static layer. Two types of entities are represented at the inference layer: meta-classes and knowledge sources. Meta-classes describe the role domain-concepts can play in reasoning. For example, a domain concept like 'infection' can play the role of a finding in a consultation process, but it may also play the role of hypothesis. Knowledge sources describe what types of inferences can be made on the basis of the relations in the domain layer. Examples are the specification and the generalisation of knowledge sources, which both make use of a subsumption relation in the domain layer.
The third layer is called the task layer. At this level the basic objects become goals and tasks. Tasks are ways in which knowledge sources can be combined to achieve a particular goal.
The fourth layer is the strategic layer in which knowledge resides which allows a system to make plans - i.e. create a task structure - to control and monitor the execution of tasks, to diagnose when something goes wrong and to repair impasses.

1. Static knowledge layer
2. Inference layer
3. Task layer
4. Strategic layer

5.4 Item Characteristics Dimensions

Although these dimensions are of a completely different nature, they are in the context of our research purposes of importance. Items are used to measure the mastery of (prior) knowledge. Moreover, test items are clues to the activation of prior knowledge. The way the individual is instigated to show his mastery of knowledge and the way certain knowledge is (re)presented to the learner can also be related to the "structure of knowledge issue".

5.4.1 Number of Propositions Dimension

A proposition is the smallest unit that can be considered as a separate statement that can be judged as true or false. In schema theories (Dochy & Bouwens, 1990), propositions or nodes have a central function in the structure of schema. It is assumed that the amount of propositions determines the degree of structure needed to answer the item correctly. According to the mean amount of propositions in our items, we found that most items had 4 to 9 propositions. Three parameters have been identified in relation to this dimension :

1. < 5 propositions
2. > 4 < 10 propositions
3. > 9 propositions

5.4.2 Information Level Dimension

The stem of an item is the general information which is given and which must not be evaluated as true or false. This correct information proceeds the question(s) for which this information should be taken into account. A stem can be connected to one or more subsequent questions. Therefore, the spatial and logical distance between the general information part of an item and the question part of the whole item is larger than for simple items without stem.

1. Items with a stem
2. Items without a stem

5.4.3 Representation Level Dimension

Adhering the representation structure, used in the research of Boekaerts (1979), i.e. visual, verbal and symbolic representation, we used four parameters along this dimension. These parameters are also closely related to the four content levels in Guilford's structure of intellect model: figural, symbolic, semantic (the verbal factor) and behavioral (nonverbal information) and the Twyman (1985) categories : verbal, pictorial and schematic. Since test-items are always - in part - based on a textual representation of information, our dimension distinguishes only between parameters that are combinations of knowledge representation.

1. Textual-graphical
2. Textual
3. Textual-schematic
4. Textual-symbolic

5.5 Hierarchical and Non-hierarchical Dimensions.

Of importance in this theoretical discussion of the dimensions for the construction of knowledge profiles is the hierarchical or non-hierarchical nature of the dimensions. Empirical validation of the dimensions and their further application, has to take this particularity into account. Table 1 on the next page presents a summary. An asterix (*) indicates that the dimension is considered to be of a hierarchical nature.

Table 1 : Hierarchical and non-hierarchical dimensions

Profile dimensions	Hierarchical
Economics subdomains dimension	-
Curriculum dimension	-
Curriculum accent dimension	-
Propositional dimension	-
Node relation dimension	-
Cognitive complexity dimension	*
Behavioral dimension	*
Content dimension	*
Epistemological dimension	*
Layers of knowledge dimension	*
Number of propositions dimension	-
Information level dimension	-
Representation level dimension	*

6. Looking for empirical evidence : data collection, data screening end general validation procedure

6.1 Data Collection

When looking for empirical evidence to support the theoretical assumptions and theoretical constructs in the former part of this text, research data were gathered from an experimental sample. A test - consisting of 154 items and called the Domain-Specific Knowledge State Test (DS KST) - was administered to 627 students of the University of Maastricht and the Dutch Open university, starting studying "economics".

Construction of the domain-specific knowledge state test (DS KST)

There is evidence that learning is much more domain-specific that earlier learning theorists believed (Dochy, 1992). It is obvious that domain-referenced testing provides a reasonable possibility of measuring an individual's knowledge status and of tracking his progress within a certain domain. Apart from that main reason, there is more evidence to account for increasing application of Domain-Specific KS Tests.

First, it can be assumed that the learning process is also influenced by prior knowledge that is broader than strictly subject-specific prior knowledge. For this reason, a domain-specific test was developed covering the whole domain (up to a certain degree of difficulty of specialization). In our case we are concerned with the domain of economics.

Second, differences between students concerning specific subjects are sometimes rather large. In this case, a test at beginners level would not be able to bring to light all of the differences between the students. The chances of doing this is greater when using a test related to end terms, i.e. one whose level corresponds to the end of the second year university study.

Third, because some students have already gained a great deal of experience in their working environment or have already attained a relatively high educational level (some higher vocational education degree or a university degree), a test set at beginner's level (final VWO level) would not be capable of measuring part of the prior knowledge state.

Fourth, the recent trend known as 'open learning' which uses flexibility as a key concept, is strongly related to the use of DS tests. Open learning tries to take the students' prior knowledge into account and allows them to study at their own place and pace. Students have a large degree of freedom in choosing educational media and objectives. A sudden openness related to objectives and other choices needs an appropriate assessment instrument. Domain-specific tests seem to be appropriate. Other instruments rather neglect the primary conditions of open learning. DS tests not only reveal measurement results, but also information and guidelines to attack deficiencies. Testing should serve the learning process.

A fifth argument is the psychometric quality of the item bank for DS tests. The amount of available items for a course is often restricted and does not allow the removal of items on the basis of insufficient psychometric quality (validity, reliability, p-value). This problem disappears when using the larger item banks for DS tests.

A sixth reason in favour of DS tests is the possibility of using them for different functions, i.e. assessment of entrance level, of progress and certification. Further, it allows to focus on different dimensions that exceed beyond the content level.

Finally, there is the trend towards internationalization of higher education and co-operation between European universities. In this respect, DS tests enable comparisons of individual students and comparisons of institutions to be made.

For these reasons, a domain-specific test was developed. This test, which is aimed at the whole domain of economics, is set at the level which should be attained by the end of the second year of university study. The heterogeneity of the test population (or student population) is so great that a test at beginner's level would not be able to bring to light all of the differences between the students. After all, it can be assumed that students with years' of working experience in, for instance, the financial sector, or students who have obtained other academic (WO) or higher vocational education (HBO) diplomas will have advanced further than the beginners level in certain areas, and may achieve a score approximating to the final 'economist' level. In other words, because some students have already gained a great deal of experience in a working environment or have already attained a relatively high educational level, a test set at beginner's level (final VWO level) would not be able to measure some of the prior knowledge state.

The University of Limburg possesses a wealth of experience in constructing tests, especially tests associated with end terms. Our DS Knowledge State Test was constructed as a representative random test of items selected from the item bank of the Economics Faculty of the University of Limburg. The items in the data bank are classified in 9 subject areas, viz.: reporting, financing, organization, marketing, macro-economics, micro-
economics, public finances, international economic affairs and behavioral and social sciences.

If test analysis is to be quick and the method of answering the items is to be simple, multiple-choice or true/false items must be used. This test consists of multiple-choice questions which can be answered with true/false or ?. The ?-alternative is taken as a third alternative in order to prevent guessing.
There is no problem in relation to validity since the test clearly represents - to a very large extent - the domain and has been developed by a team of domain experts. The psychometric quality problem is especially in game when determining the reliability of the test. If we calculate the alpha-coefficient, the test can be considered as very reliable: alpha =.93. This high reliability is probably caused by the fact that the test is long (154 items), which gives a high alpha-coefficient. Moreover, the test is not necessarily homogeneous which implies that basic assumptions on which the calculations of the alpha-coefficient are based could have been violated.

Table 2: Alpha-coefficients for the parameters of the economics subdomains and curriculum accent dimension and mean alpha-coefficients

Parameters	α-coefficient	N items	αm
Economics subdomains dimension			
Reporting	.57	18	
Finance	.64	18	
Organisation	.69	18	
Marketing	.63	18	
Macro-economy	.71	25	.63
Micro-economy	.74	25	
Public	.51	11	
International Economics	.55	11	
Behavioral & Social Sciences	.63	10	
Curriculum accent dimension			
General economics	.93	139	.69
Quantitative economics	.45	15	

One solution to this problem might be to check the reliability of sub-parts of the test, making use of the knowledge profile dimensions. Calculation of alpha was repeated for two of these dimensions (economics sub-domains and curriculum accent), in order to be able to present a mean reliability score. When reorganizing the test into more homogeneous sub-parts, the alpha-coefficient and a mean alpha-coefficient were calculated. The results of this procedure are summarized in table 2. To enable the figures to be judged in a better perspective, the number of items within each sub-group of items is also given. Mean alpha seems to be >.63. This reliability score is - taking into account the restricted number of items in certain sub-parts of the test - acceptable for our research purposes.

The 154 items were analyzed - separately - by the members of the research group. In reviewing the items, the researchers attempted to classify each item along each of the 12 dimensions, discussed in part 5 of this report.

Table 3 : Applying profile dimensions - success or failure

Economics Subdomains Dimension	+
Curriculum Dimension	+
Curriculum Accent Dimension	+
Propositional Parameters Dimension	-
Node Relation Dimension	+
Cognitive Complexity Dimension	-
Behavioral Dimension	+
Content Dimension	+
Epistemological Dimension	+
Layers of Knowledge Dimension	-
Number of Propositions Dimension	+
Information Level Dimension	+
Representation Level Dimension	+

In relation to three dimensions the researchers encountered too many difficulties (table 3) :

- The "Propositional Parameters" dimension could not be applied since all items consist of more than one node. But this dimension was helpful as a base to determine the "Node Relation" parameter of an item.
- The parameters along the "Cognitive Complexity" dimension were too vague and not defined at an operational level to be applied consistently. Moreover, they implied a reformulation of the items, which was not acceptable.
- The "Layers of Knowledge" dimension was felt to be a duplicate of the "Behavioral Level" dimension.

In relation to the other dimensions an inter-rater reliability was obtained > .8**. If there was discussion in relation to the categorization of a specific item along a dimension, discussion resulted in a consensus on the final classification of the item.

6.2 Data Screening

After screening and reorganizing the items, the raw item scores were used as the base for calculating new subscores for each parameter along each dimension. To be able to compare the parameter subscores, mean % scores were calculated. This helped to define the data set in table 4. This table presents an overview of the mean % scores, the standard deviation and the minimum and maximum score in relation to each parameter on each dimension. The last column indicates the number of test items on which the calculation of the parameter scores is based. In association to most parameters, the score is based on a sufficient number of test items. Only the "node relation" and the "curriculum accent" dimension present some problems since the numbers of items is not sufficiently equilibrated over all the parameters of these dimensions.

Table 4 : Descriptive data of all the parameters for each dimension

	m	σ	min.	max.	n
ECONOMICS	42.85	19.14	.00	100.00	154
REPORT	25.63	14.69	.00	83.33	18
FINANCE	26.37	15.63	.00	72.22	18
ORGAN	34.50	18.58	.00	83.33	18
MARKET	35.74	16.80	.00	83.33	18
MACRO	25.66	14.67	.00	72.00	25
MICRO	24.44	14.89	.00	80.00	25
PUBLIC	32.93	18.50	.00	90.91	11
INTERNAT	26.91	17.99	.00	81.82	11
BEHAV	17.38	17.80	.00	80.00	10
LEVEL1	30.64	12.63	.00	65.69	102
LEVEL2	22.31	15.91	.00	78.85	52
QUANT	24.36	13.77	.00	73.33	15
GENERAL	28.20	12.80	.00	66.91	139
REASON	27.91	34.42	.00	100.0	2
INITIATE	20.45	18.17	.00	87.50	8
CONSEQ	29.09	13.21	.00	72.41	58
MANNER	39.39	23.77	.00	100.00	5
PROPERTY	26.93	12.65	.00	69.14	81
KNOW	29.82	15.37	.00	79.17	24
INSIGHT	28.95	13.38	.00	71.72	99
APPLY	22.67	11.96	.00	70.97	31
FACTUAL	22.43	19.62	.00	100.00	6
CONCEPT	35.25	16.67	.00	80.95	21
RELAT	30.84	14.57	.00	75.00	32
STRUCT	26.48	13.52	.00	78.57	56
SKILL	24.11	12.92	.00	76.92	39
KIDENT	29.22	16.18	.00	80.00	15
KCONCEPT	36.75	19.85	.00	90.00	10
EPISTO	28.02	13.39	.00	72.62	84
LOGICAL	30.27	17.67	.00	86.67	15
IMPLEM	22.40	11.89	.00	70.00	30
< 5	27.16	12.63	.00	67.07	82
> 4 < 10	13.63	6.08	.00	31.00	44
> 9	6.93	4.18	.00	22.00	28
WITHS	29.92	13.45	.00	68.00	105
WITHOUT	39.32	19.67	.00	100.00	49
TEXT	28.77	13.25	.00	67.68	99
CONCRET	36.58	20.71	.00	88.89	9
SCHEME	28.71	16.26	.00	71.43	14
SYMBOL	22.47	12.68	.00	68.75	32

Considering the data in the table, some preliminary conclusions can be drawn in relation to the value of the dimensions and parameters to specify c mponents of expertise :

- The mean % scores for the specific parameters along a dimension show remarkable differences.
- Also the σ values vary to a large extent, even when excluding the values based on a too small number of items (last column).
  The high σ-values indicate that the score distribution does not represent a normal distribution of scores. The fact that the results are based on a prior knowledge state test are responsible for this large score-distribution.
- The fact that for all parameters/dimensions the minimum value is 0, indicates that the test has been difficult for the students. On the other hand, some student are able to show their mastery of economics by obtaining relatively high mean % scores.

Further screening of the data reveals :

- There are no missing data.
- The large standard deviations, mentioned above, might imply that the distribution of the scores is not normal (Skewness, Kurtosis) and that the distributions are influenced by outliers. The Kurtosis-values vary between -.637 and .989. Skewness-values vary between .080 and .881. Both measure suggest acceptable distributions of the data. To check multivariate normality, box-plots of the data have been screened. They reveal there are extremes and outliers, but their number remains restricted. Moreover, outliers are expected (given the fact we measure mastery of expertise) and considered part of the particular distribution of our data. They are properly part of the population from which we intend to sample.
- Analysis of the correlation matrix reveals high r-values, but never > .8 which implies that all distinctive variables are non-redundant and do not measure comparable issues[1]. Multicollinearity is therefore not a problem.
- Homogeneity of variance-covariance matrices is a necessary assumption if we compare the subscores along the different dimensions. Calculation of the Cochrans C and Bartlett-Box F and their respective significance-levels, indicate that this assumption is not violated.

6.3 Validation Procedure

When validating the different knowledge profile dimensions, two approaches will be adopted :

- an analysis of the extent to which the variables along the dimensions give information about different components of expertise;
- an analysis of the discriminatory power of the dimensions to make apparent expertise differences between student sub-populations.

In part 7 and 8 of this text, the first approach is adopted, whereas in part 9, the profile dimensions are used to compare a variety of student-subpopulations. In view of the first approach, a distinction is to be made between hierarchical and non-hierarchical dimensions. Hierarchical dimensions imply consecutive intercorrelations between the variables. This can be evaluated by applying multiple linear regression techniques. Non-hierarchical dimensions imply low correlations between the dimension variables. This is to be evaluated by analysis of the correlation matrix.

7. The value of the non-hierarchical dimensions

7.1 Economics Subdomains Dimension

As described in part 5.1 of this report, the economics-subtopics reflect a rather practical subdivision of the economics domain in view of educational purposes. It is therefore to be foreseen that the mean % scores for the different economics subjects do correlate to a certain extent (all r-coefficients are statistically significant at the 1% level)[2], since this subdivision does not (and cannot) reflect an absolute and objective split-up of the economics domain.

[1] Tabachnik & Fidell (1990, p.87) use a limit of r > .9 to distinguish redundant variables.

[2] When indicating significance levels in the next part of this text ** indicates p < .01 and * indicates p < .05.

Table 5 : Correlation Matrix subtopic-dimension

	1	2	3	4	5	6	7	8	9
1. Report	1.00	.633	.581	.556	.427	.475	.377	.350	.442
2. Finance		1.00	.683	.634	.552	.527	.509	.503	.518
3. Organ			1.00	.681	.492	.483	.472	.446	.483
4. Market				1.00	.543	.519	.497	.479	.500
5. Macro					1.00	.662	.567	.573	.514
6. Micro						1.00	.481	.549	.520
7. Public							1.00	.562	.456
8. Internat.								1.00	.474
9. Behav.									1.00

The data in table 5 confirm our expectations. The different economics subtopics are intercorrelated. If we concentrate only on the r-coefficients > .6, we get the following picture :

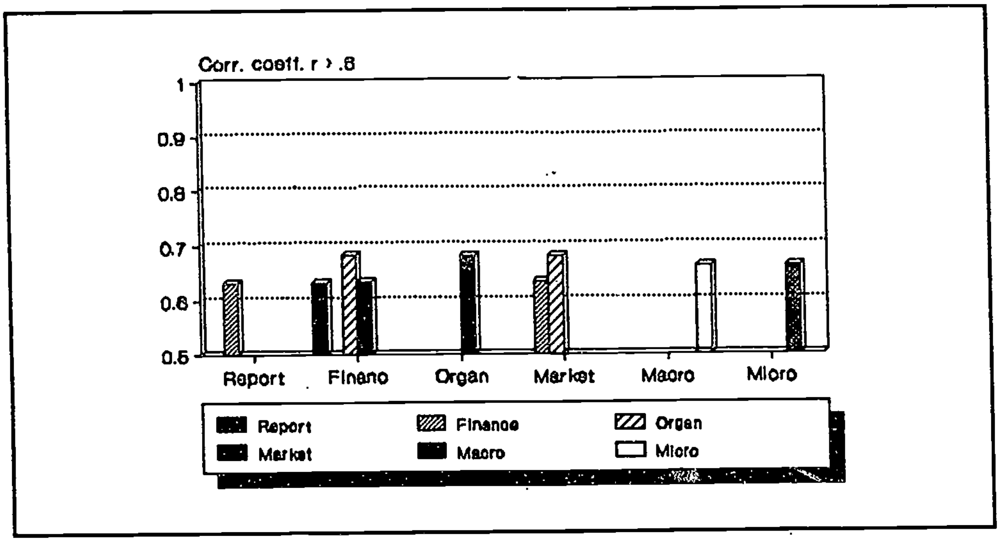

Figure 2 : Correlation structure Economics subdomains dimension

The six following subtopics are highly intercorrelated : "Report, Finance, Organ, Market, Macro & Micro". This can be due to high degree of content-links between these economics subdomains or the fact that mastery of a particular subdomain explicitly builds on the mastery of another domain. This is particularly important in relation to the subdomain "Finance" and "Marketing".

If we execute a linear regression analysis[3] by entering the mean % scores of the subdomains "Report, Macro and Organ" stepwise in the regression equation, we find that up to 50.3 % of the variance in the "Finance" is accounted for by these three subdomains.
In a comparable way, stepwise regression from "Organ & Finance" on "Marketing" reveals that up 51.6 % of the variance in the "Marketing" mean score is accounted for by the scores for "Organ & Finance". This interdependence can be taken into account when setting up learning activities or guidance initiatives for students.
An alternative interpretation of the correlation coefficients links the mastery of the different economics subdomains to the previous experiences of students with the particular subtopics in their secondary education. A subpopulation of the starting university students might have got an introduction to certain economics domains, such as micro- and macro-economics and reporting (accountancy). The subsequent high

[3] If regression analysis is executed, also the residuals are analyzed in order to detect violations of regression assumptions (linearity, normality of the distribution of the dependent variable, constant variance). If violations are detected, this will be reported.

scores for these subtopics in the expertise test are therefore expected to correlate to a certain extent.

7.2 Curriculum Dimension

In the prior knowledge test, the test items were subdivided into two course level sets : "Level1" grouping items that evaluate mastery at the first year level and "Level2" that evaluate the mastery at the second year level.
As table 4 shows, the mastery of both the level1 (m = 30.64) and the level2 (m=22.31) items is restricted. As expected, the "level2" total subscore is the lowest indicating the higher difficulty level of this set of items. Content experts indicate that mastery of level1 items is to a certain degree related to mastery of "level2" items since part of the "level2" course content builds on the mastery of "level1" items. This is confirmed by linear regression analysis. This analysis indicates that the "level2" mean % score of the students helps to explain 38.2 % of the variance in the "level2" mean % scores[4].

7.3 Curriculum Accent Dimension

A generally accepted subdivision in economics is splitting up the domain into general economics and quantitative economics. Our expertise test, does only reflect this subdivision to a very limited extent since only 15 items can be classified as quantitative economics questions whereas 139 items concentrate on the mastery of general economics knowledge. It is therefore predictable that the test results along this dimension will not be very useful. Analysis of the mean scores (m_{quant} = 24.36; $m_{general}$= 28.20) and standard deviations (σ_{quant} = 13.77; $\sigma_{general}$ = 12.80) in table 4 indicate that the students master the two types of economics knowledge to a comparable extent. Moreover, the intercorrelation between both measure is rather high (r =.6197**). The subdivision between quantitative and general economics is therefore not able - to a sufficient extent - to separate knowledge components.

7.4 Node Relation Dimension

The correlation matrix on the next page clearly indicates that most parameters along this dimension can be clearly separated from each other. The "property" parameter is highly correlated with the "initiate" (.6428**) and the "consequence" (.8523**) parameter.

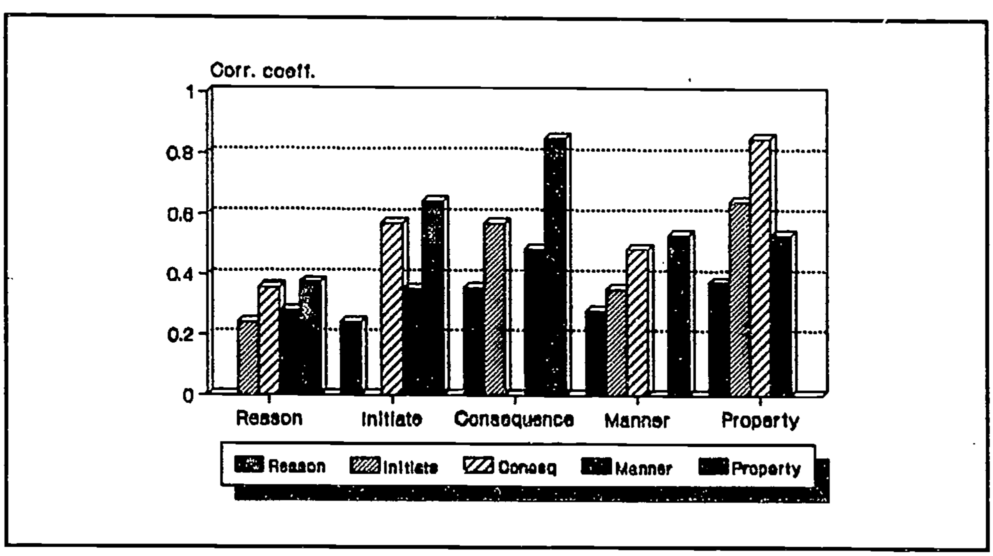

Figure 3 : Node Relation Dimension - Correlation structure

[4] When executing linear regression analysis, basic assumptions have been checked. No violations have been detected, for instance the distribution of the residuals is normal.

7.5 Number of Propositions Dimension

Since the number of propositions in test items can be considered as a measure comparable to difficulty levels, a gradual decrease in the mean scores for the three variables on this dimension is expected. The data in table 6 confirm our expectations ($m_{propos1}=27.18$; $m_{propos2}=13.63$; $m_{propos3}=6.93$). Analysis of the correlation matrix reveals striking results (all r-coëff. are statistically significant, $p < .001$):

Table 6 : Correlation matrix : Number of propositions

	1	2	3
1. < 5 propositions	1.00	.765	.803
2. > 4 < 10 propositions		1.00	.761
3. > 9 propositions			1.00

The results in table 6 can be interpreted as follows : students who are able to solve items, consisting of > 9 propositions (3) are able to solve items consisting of a number of proposition > 5 < 10 (2) and are certainly able of solving items consisting of < 5 propositions (1). This is confirmed by a linear regression analysis : the scores for items with > 9 propositions explain 64.3 % of the variance in the scores of items with < 5 propositions. If we add the scores for items with > 4 < 9 propositions to the regression equation, up to 70 % of the variance is accounted for.

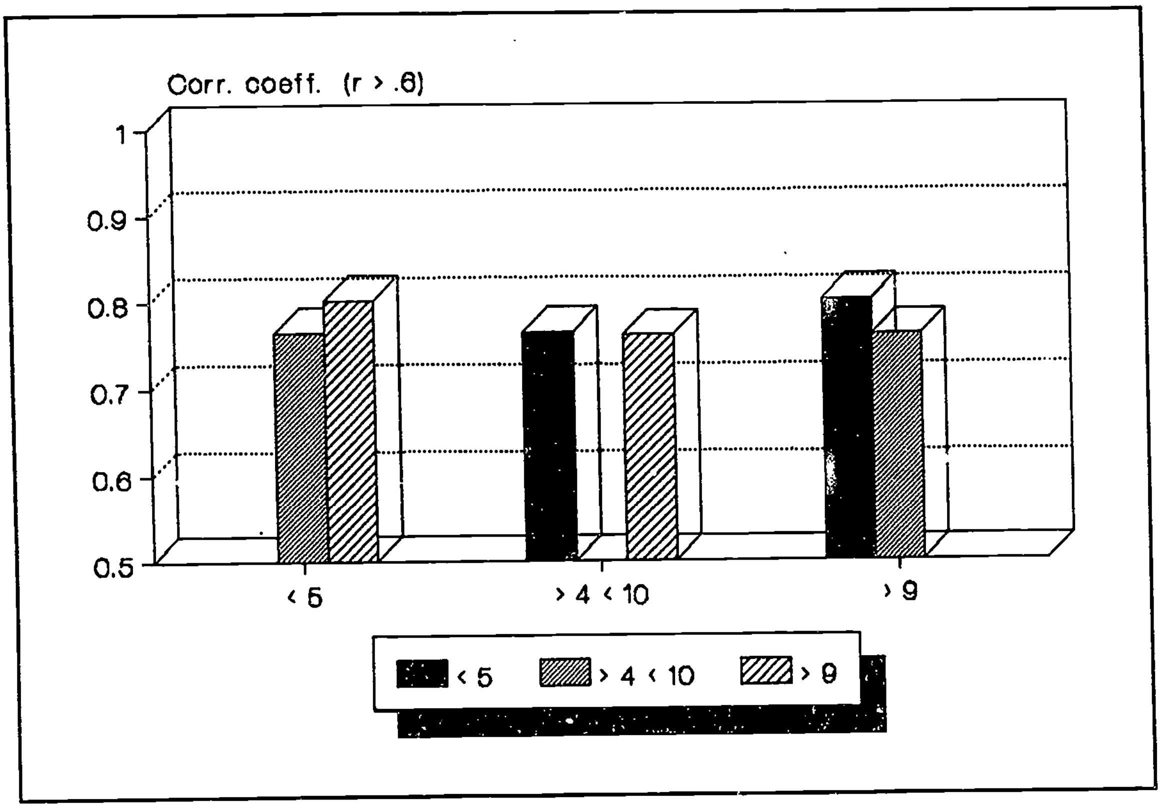

Figure 4 : Intercorrelation between mean % scores for "Number of Propositions"

7.6 Information Level Dimension

As explained in the theoretical part of this text, items with a stem have in common that the spatial and logical distance between the basic information and the question part of the item is greater than in items without a stem. To a certain extent, this dimensions can be compared to the "number of propositions dimension".
It is expected that items with a stem are more difficult than those without a stem. This is confirmed by the data in table 4 when comparing the mean % scores and σ ($m_{with\ stem}$ = 29.92; $m_{without}$ = 39.32; $\sigma_{with\ stem}$ = 13.45; $\sigma_{without}$ = 19.67). This is also confirmed by the analysis of the correlation matrix. Both variables are highly correlated (r = .8246**). This can be explained as follows : the students being able to solve items with a stem, are to a very high extent able to solve items without a stem.
Linear regression confirms this hypothesis : the mean % scores for the items with a stem help to explain 68 % of the variance in the scores for items without a stem.

8. Validating hierarchical dimensions

Up to 5 dimensions have been identified as being "hierarchical" (table 1). As explained in part 6.3 hierarchical dimensions imply consecutive intercorrelations between the parameters along the dimensions. This can be evaluated by applying multiple linear regression techniques. Beforehand, some additional remarks are to be made because we isolate profile dimensions from the economics subdomain dimension. In validating the hierarchical nature of the dimensions abstraction is therefore made of the subject matter on which the items are based. There is as a consequence no control on interaction effects between the dimensions and the economics subdomains dimension. If e.g. items evaluating the mastery of "micro-economics" at the "insight" level are compared to items evaluating the mastery of "finance" at "application" level and the latter economics subdomain is much more complex and difficult than the former, the analysis results in relation to the hierarchical structure of "insight" and "apply" along the behavioral dimension might be disturbed.

8.1 Behavioral Dimension

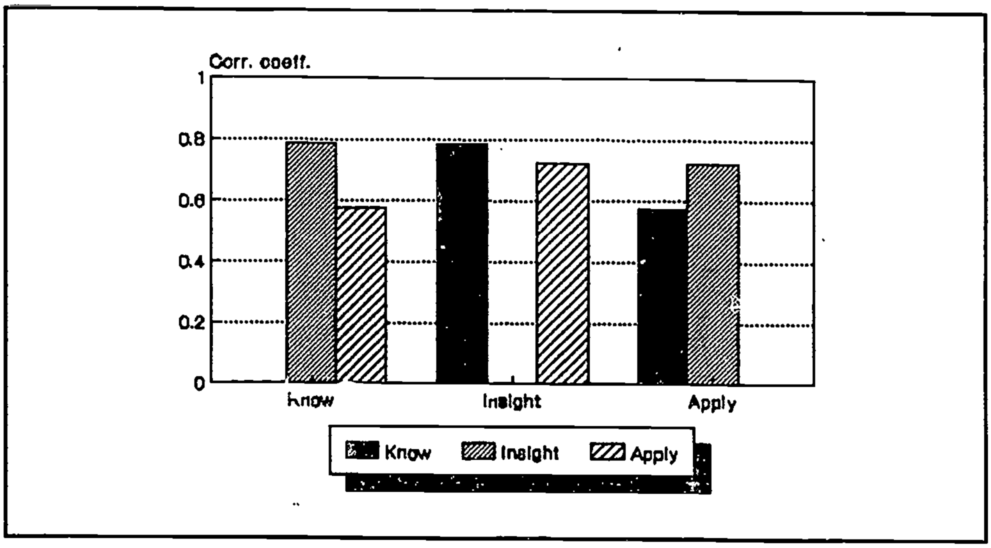

Figure 5 : Behavioral Dimension - Correlation structure

Figure 4 clearly indicates features of the hierarchical nature of this dimension, although the highest correlations are observed in relation to items measuring the mastery of items at insight-level (insight-apply = .72246**; insight-know = .78633**). The latter fact is consistent with earlier validations of this kind of dimension (the taxonomic classification of Bloom : knowledge - comprehension - analysis - synthesis and evaluation). Keeves (1988, p.346) refers e.g. to a validation by Ebel, Hill & Horn.

The three lowest levels, "knowledge, comprehension and application", are comparable to our three first behavioral levels and are found to be well-hierarchical. Higher up in the hierarchy a branching takes place. If we extend our analysis to a regression analysis in which we evaluate the interrelation between the three consecutive behavioral levels, we get the following picture :

Table 7 : Regression analysis behavioral dimension

Independent variable	Dependent variable	% variance explained
Know	Insight	61 %
Know*, Insight	Apply	52.2 %

When entering the parameters "know" and "insight" in the regression equation, the contribution of the parameter "know" is considered too low[5] and therefore excluded from the regression equation.
The results in table 7 help to confirm the assumptions about the hierarchical nature of this dimension since the preceding parameter(s) always help to explain the major part of the variance in the mean % scores for the subsequent parameter along the dimension.

8.2 Content Dimension

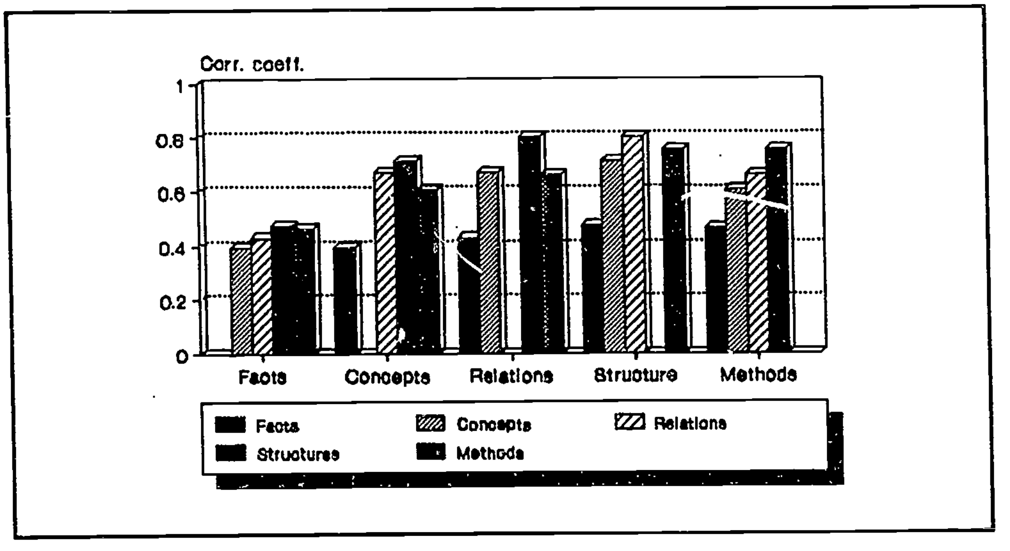

Figure 6 : Content Dimension - Correlation structure

In the picture it can clearly be seen that the correlation coefficients increase along the consecutive parameters of this dimension. This can be considered as a first indicator to support the hierarchical nature of this dimension. Only in relation to the parameter "methods" there is a minor decrease in the r-values.

[5] The limit of PIN=.05 is reached.

Table 8 : Regression analysis content dimension

Independent variables	Dependent variables	% variance explained
(F)acts	Concepts	15.5% F
(F)acts - (C)oncepts	Relations	47.9% C F
(F)acts - (C)oncepts - (R)elations	Structures	71.0% R C F
(F)acts - (C)oncepts - (R)elations - (S)tructures	Methods	59.6% S F C R

The data in table 8 are very consistent. At the consecutive levels, the hierarchy between "facts - concepts - relation and structures" is respected. In the second column the letters and the order in the letters refer to the pattern in which the independent variables help to explain the variance in the dependent variable. This order always respects the supposed hierarchy.
Only at the skills-level, there is a deviant structure. This suggests that "skills" might be of a more general and complex nature than "facts, concepts, relations and structures".

8.3 Epistemological Dimension

As explained earlier, this dimension can be considered as a combination of the behavioral (8.1) and content dimension (8.2). The structure is especially based on the assumption that the lower behavioral parameters are rather linked with lower content parameters (e.g. knowledge of a fact) and that the higher behavioral parameters are rather linked with the higher content parameters (e.g. application of a theory).
This mixture of two hierarchical dimensions might impose difficulties in terms of their interaction. The correlation matrix is e.g. not helpful to recognize - at first sight - the hierarchical structure.

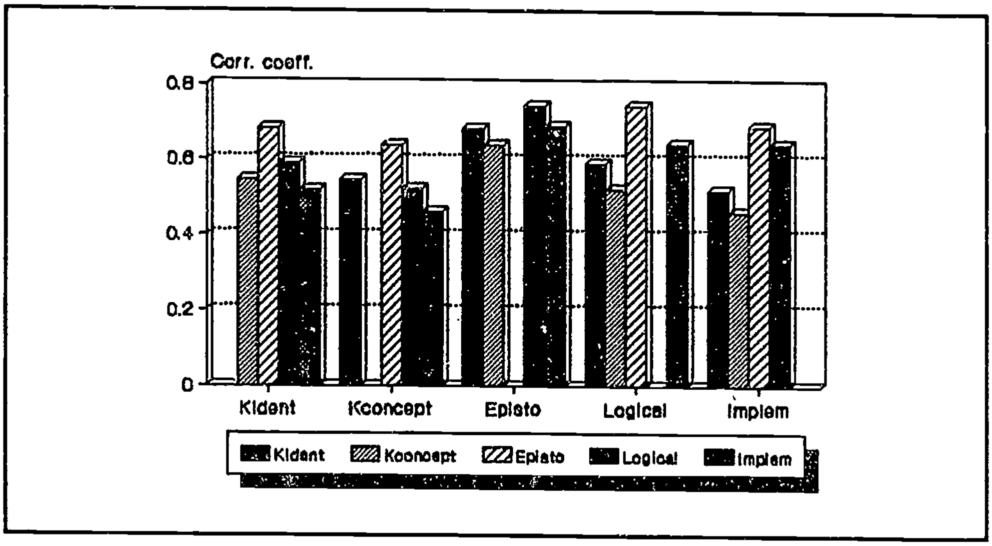

Figure 7 : Epistemological Dimension - Correlation structure

There are some high correlations between the lower and higher parameters along this dimension. But nevertheless, the highest correlations are observed when the distance between a high and another parameter along the dimension is small (implem-logical) and the lowest correlations are observed when the distance between a high and another parameter is large (e.g. "implem - kident).
A regression analysis in which the parameters are evaluated in terms of their explanatory power for the consecutive parameters gives us the following picture :

Table 9 : Regression analysis - epistemological dimension

Independent variables	Dependent variable	% expl. variance
(Ki)dent	(Kc)oncept	29.7 %
(Ki)dent - (Kc)oncept	(E)pisto	56 % Ki Kc
(Ki)dent - (Kc)oncept - (E)pisto	(L)ogical	56 % E Ki
(Ki)dent - (Kc)oncept - (E)pisto - (L)ogical	(I)mplem	50.7 % E L

The regression analysis confirms the former preliminary conclusions. The hierarchy is disturbed but still present. The proportion of the variance in the consecutive parameters is always explained by the former parameters with the closest distance along the dimension. Moreover, the proportion of explained variance is > 50 %. Lower level parameters are sometimes excluded from the regression equation.

8.4 Representation Level Dimension

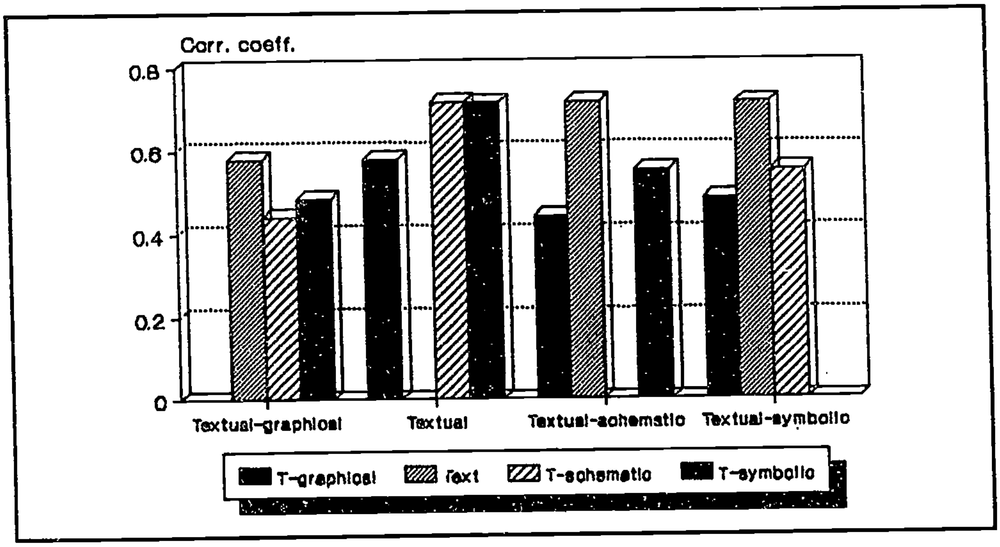

Figure 8 : Representation Level Dimension - Correlation structure

Figure 7 reveals high intercorrelations between all parameters and the "text" parameter. This is to be expected since the test items are never based solely on concrete, schematic or symbolic information. The items are a priori based on textual information which is supported, enhanced, enriched or supplemented with information of another nature. Nevertheless it is remarkable in table 4 that the mean % scores for the subsequent parameters decrease from 36.58 % to 22.47 %, suggesting higher difficulty levels for the items based on higher order representation levels.

Table 10: Regression analysis representation level dimension

Independent variables	Dependent variable	% expl. variance
(C)oncret	(T)ext	33.0 %
(C)oncret - (T)ext	(Sc)heme	51.0 % T
(C)oncret - (T)ext - (Sc)heme	(Sy)mbol	51.6 % T C

Table 10 confirms the expected disturbance of the hierarchical nature by the predominance of the textual representation mode in most items. The "text" parameter is always the parameter responsible for the highest proportion of the variance in the subsequent parameter.

9. The discriminatory power of the knowledge profile dimensions

To validate the 10 knowledge profile dimensions in an additional way, their power to make explicit differences in expertise between subpopulations of students has been determined. Three subdivisions in student populations have been researched :
- The difference(s) between students studying in differing university contexts.
- The difference(s) between students with low and high levels of expertise.
- The difference(s) between economics and law students, studying the same course.

A more detailed description of these three investigations can be found in Dochy & Valcke (1992), Valcke & Dochy (1992) and Wagemans, Valcke & Dochy (1992).

9.1 The difference(s) between students studying in differing university contexts.

Students have - in the Dutch context - the option to choose for a variety of university contexts and educational approaches at university level (e.g. problem centred approach, experiential learning, distance education, etc). A relatively new development (since 1985) in this perspective is the provision of "open and distance university education" by the Dutch Open university (Ou). The question can be put forward whether this new university setting is just another higher education institution enriching the variety of already existing provisions or whether the Open university answers the need of (a) specific student population(s); e.g. second chance, older students, female students, handicapped people, foreign students, post-university students ? A way to look for answers to this question is to analyze - by interviews, questionnaires, etc. - demographic variables of the actual student population of the Ou.

Another approach goes beyond these surface variables and analyzes in more detail the expertise of the students opting for the Ou. The research question, which results from this approach is whether the expertise of the students, opting for this study context is different from students studying at regular universities. Making use of the 10 knowledge profile dimensions, an extensive analysis has been executed on research data of students studying economics at the Dutch Open university (Ou) and students studying economics at the University of Maastricht (RL) where a problem centred approach towards education is adopted.

Although the overall prior knowledge mean % score for the economics domain is not significantly different between the Ou- and the RL-student population, a univariate analysis of the knowledge profiles helps to enlighten obvious and significant differences in the complex composition of components of prior knowledge. These results are confirmed and reinforced by the results of the profile analysis (multivariate analysis of variance). The results of the profile analysis (parallelism test and discriminant analysis) help to reveal specific and significant differences between the profiles of both student populations. Up to seven of the ten knowledge profile dimensions prove to be of relevance (table 11). Especially the "content dimension" and the "epistemological dimension" were helpful to describe these differences.
A further extension of our profile analysis (flatness test) helps to induce further evidence to support the validity of the knowledge profile dimensions, since all profiles are non-flat. This implies that all dimensions are helpful to identify a specific structure in the mastery of expertise. Following this structure, the mastery of certain components of expertise is better than for other components.

Table 11 : Profile analysis data for the parallelism test

Profile Dimension	Wilk's λ or F	p
Economics Subdomains	.5580	.000
Curriculum Dimension*	44.24*	.000
Curriculum Accent*	00.13*	.720
Node Relation	.7777	.000
Behavioral	.8891	.000
Content	.6664	.000
Epistemological	.7474	.000
Information Level*	00.00*	.984
Number of Propositions	.9798	.162
Representation Level	.8293	.000

9.2 The difference(s) between students with high and low levels of overall expertise.

The overall test score of students with low and high levels of expertise can easily be compared. The student group can be subdivided into two groups, consisting e.g. of 50% (or 25%) of the students with scores lower than the mean (Low expertise LE) and a group with 50% (or 25%) of the students with scores higher than the mean score (High expertise HE). It is obvious that - when comparing these subpopulations - significant differences are observed in the overall test scores, certainly when taking the extreme quartiles into account. However, this is not that obvious when looking at the middle quartiles of the sample as we did. A more refined analysis of the test scores, making use of the ten knowledge profile dimensions can help to clarify in a much more specific way the specific small or large differences between students with low and high levels of expertise.

Making use of the data gathered among students, studying at the Dutch Open university and at the University of Maastricht, a comparable analysis as described in part 9.1 was executed. Some problems were encountered in relation to basic statistical assumptions about the research data when splitting up the population into two groups consisting of 50%-50%. Therefore, only the data gathered among the research population consisting of 25% of the students with mean % scores higher and 25% of the students with mean % scores lower than the mean were used in the profile analysis.

All the knowledge profile dimensions help to differentiate - following the results of the univariate analysis of variance - between LE and HE students. All differences between both student populations are significant, whether we consider the 25%-25% or the 50%-50% group. The reader might conclude that the dimensions have not been helpful to detect very specific contrasts between LE and HE students. But, the specification of the 25%-25% group has proven to be useful since more distinctive differences between low and high performers could be detected than comparing the 50%-50% group. Expectations about the knowledge profiles - based on our theoretical considerations - have been largely confirmed (e.g. hierarchical nature, subsequent difficulty levels, etc.).

The results of the profile analysis (parallelism test and discriminant analysis) are shown in table 12.

Table 12 : Results of the parallelism test in profile analysis

DIMENSION	Wilks λ or F	p_λ or p_F
Economics subdomains	.96459	.232
Curriculum level*	20.94	.000
Curriculum accent*	536.17	.003
Node relation	.96662	.041
Behavioral level	.93784	.659
Content level	.97667	.140
Epistemological	.24876	.000
Number of propositions	.79462	.000
Information level*	53.55*	.000
Representation level	.95832	.006

The results help to detect specific significant differences in the following knowledge profiles of LE and HE students : curriculum level, curriculum accent, behavioral level, number of propositions, information level and representation level. The results of the flatness test indicate that all dimensions result in non-flat knowledge profiles. This implies that all dimensions are helpful to identify a specific structure in the mastery of expertise. Following this structure, the mastery of certain components of expertise is better than for other components.

9.3 The difference(s) between economics and law students, studying the same course.

"Diploma type" has been an independent variable used regularly in our research (Dochy & Bouwens, 1990b; Dochy, Valcke & Wagemans 1991b; Dochy, 1992). This research body was helpful to conclude that "diploma type" is not useful as a relevant indicator of expertise since conflicting results are obtained from the consecutive studies. But the question endures in the context of this text about knowledge profiles. Are economics (ES) and law students (LS) for instance - notwithstanding non-significant differences in overall expertise - different when looking at their knowledge profiles?

In the actual analysis, the test results of law students and economics students, studying at the Dutch Open university were used for further analysis. These students have subscribed for the course "Economics & Money" or "Balance sheet, Profit and Loss Account and Administrative Procedures" at the Dutch Open University. The two courses are part of the compulsory program of different diploma lines, such as "Dutch Law" and "Economics".

The results of the univariate analysis of variance when using the knowledge profiles dimensions are not helpful to identify more specific and significant contrasts between both student-groups. This affirms our earlier research findings showing that "student type" is not a relevant "indicator" of expertise (Dochy & Valcke, 1991; Valcke & Dochy, 1991). The initial non-significant difference between both sub-populations (overall economics-score) are confirmed, but also the general trend that ES perform better than LS can be repeated.

The results of the multivariate analysis of variance (table 13) are also not helpful to detect specific significant differences between ES and LS. The profiles of ES and LS are parallel. The intermediate conclusion of non-significant differences between ES and LS, based on the univariate analysis cannot be revisited by a more refined analysis, based on the 10 dimensions. The only, slightly significant F-value is obtained in relation to the content-level dimension ($p=.025$).

When looking at the different components of expertise, as resulting from the flatness test (see Dochy, 1992), all dimensions/parameters help to differentiate in the mastery of components of expertise - with the exception of the "curriculum accent" and "behavioral level" dimension.

Table 13 : Results of the parallelism test in profile analysis

DIMENSION	Wilks λ or F	p_λ or p_F
Economics subdomains	.81048	.061
Curriculum*	3.03*	.086
Curriculum accent*	1.78*	.187
Node relation	.93389	.288
Behavioral	.98878	.659
Content	.85856	.025
Epistemological	.97850	.811
Number of propositions	.97880	.453
Information level*	1.67*	.201
Representation level	.93829	.197

10. General conclusions

In this report we have introduced knowledge profiles as being graphs of scores of a group or individuals on a prior knowledge state test. We defined several dimensions on which knowledge profiles can be based and tried to look beyond the subject-matter level. To validate the different knowledge profile dimensions, the parameters have been related to the knowledge state test - items and we analyzed the extent to which the parameters along the dimensions give information about the components of the PKS. The non-hierarchical dimensions suggest that they do relate to different components of the prior knowledge state. This is further supported by the profile analyses (flatness tests) when comparing different populations. The other five dimensions reveal to be indeed hierarchical, although to a different extent.

Further, we have been searching for other evidence to validate our 'knowledge profiles' by looking at the discriminatory power of the dimensions to detect the PKS differences between several student populations. These analyses will be reported more extensively in Dochy and Valcke (1992), Valcke and Dochy (1992) and Wagemans, Valcke and Dochy (1992). Although we did not expect differences between ES and LS as a results of the ANOVA, this could not be revisited by a more refined profile analysis. ES and LS do not significantly differ, but they differ in the mastery of components of expertise, as revealed from the flatness test. UL en OU students do not differ in their mean % score, but profile analyses could reveal significant differences on the knowledge profiles. Also for students of the LPKS and HPKS groups (middle quartiles), differences are found in their knowledge profiles.

Promising knowledge profile dimensions for differentiating seem to be certainly curriculum level dimension, representation level dimension, epistemological dimension, content dimension, economics subdomains dimension, and further the behavioral dimension, curriculum accent dimension, information level dimension and the number of propositions dimension. Nevertheless, their value is different relying on the group or in this case the goal of the comparison between groups.

This report is of importance since we succeeded in defining and operationalizing a new and promising approach towards the analysis of prior knowledge. It is foreseen that in situations where there are significant differences between the PKS of specific subpopulations, the profile dimensions are helpful to detect and dissect the strengths and weaknesses of the students involved. This might be a promising starting point for differentiated diagnostic and guidance approaches.

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