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ABSTRACT

A study analyzed the prior knowledge state of two university populations: students at the Open University (OU) of the Netherlands and students at the University of Limburg (UL). Analysis of the prior knowledge state was based on an extensive analysis of the literature in relation to theories, models, and practice-based strategies about the structure of knowledge. A set of four dimensions--cognitive psychological, educational psychological, psychometrical, and content based--that help to construct knowledge profiles was defined. The dimensions were used to analyze the knowledge profiles of the two populations. A knowledge state test that covered the whole domain of economics in the course "Economics and Money" was administered to 626 students; 91 UL students were randomly selected to be compared with 91 OU students. The overall economics score was not significantly different between the two populations. This score was elaborated upon by grouping items along knowledge profile dimensions. After outlining the theoretical base of these dimensions, researchers focused on the application of these dimensions to compare the knowledge profiles of the two populations. Up to 7 of the 10 knowledge profile dimensions proved to be relevant. The content and epistemological dimensions were especially helpful to describe differences. (Contains 28 references.) (YLB)

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Comparing Knowledge Profiles of Students studying at a distance University and a regular University

Is studying at a different University reflected in Differences in the Prior Knowledge State?

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- the results of the project "Prior Knowledge";
- the developments of the "Computer Assisted Testing"-project;
- the developments of "Adaptive Testing" and the IRT-applications (Item-Responds Theory); and
- the experience of the Open University with the development and use of TSS (Test service systems).

The main objectives are: (1) to get a discernment of the test and evaluation problems in the open-learning system; (2) the generation of the guide-lines, specifications, and technological instruments concerned with the use of prior knowledge and experience, flexible testing and the supervision on students during the learning process, and (3) the development of instruments which can be useful in solving the given teaching problems.

Centre for Educational Technology and Innovation
Open University

Comparing Knowledge Profiles of Students studying at a distance teaching University and a regular University

Is Studying at a different University reflected in Differences in the Prior Knowledge State?

OTIC Research Report 36

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1 Introduction

When studying at university level, students have - in the Dutch context - the option to choose from a variety of contexts and educational approaches. A relatively new development in this perspective is the provision of open and distance university education by the Dutch Open university. One can question whether students, opting for this study context are different from students studying at regular universities. A possible difference can be reflected in the prior knowledge state of these students.

The analysis of the quality and impact of the prior knowledge state has been the major focus in a large part of our earlier research. In analyzing the prior knowledge state, we have already focused on the structure of the prior knowledge state along a content dimension.

In the theoretical part of this text, we discuss - in short - a distinct approach towards the analysis of the prior knowledge state[1]. This approach is based on an extensive analysis of the literature in relation to theories, models and practice-based strategies about the "structure of knowledge". This base is exploited to define a set of "dimensions" that are helpful to construct "knowledge profiles". Four types of dimensions are illustrated : cognitive psychological dimensions, educational-psychological dimensions, psychometrical dimensions and content-based dimensions.

In the empirical part of this text, the dimensions are used to analyze the knowledge profiles of two university populations : students studying a the Open university (Ou) of the Netherlands and students studying at the University of Limburg (RL). The results of this analysis are not only important to detect specific differences in the mastery of components of the prior knowledge state between both student populations, but might also be helpful to provide further evidence about the validity of the theoretical knowledge profile dimensions.

2 Theoretical background

2.1 The Structure of Knowledge

From an instructional-psychological point of view, the structure-of-knowledge problem should be investigated in order to find out more efficient ways for using instructional technology. Our search for means to handle the prior knowledge state showed that one should take account different components of the prior knowledge state. The concept of "components" refers towards a structure in the knowledge base of the learner.
Our earlier research was helpful to detect such components of the prior knowledge state along the content dimension. But it was also suggested that the differentiation of components of the prior knowledge state along other dimensions is needed to be helpful to interfere and diagnose educational practice (Dochy and Valcke, 1991; Dochy and Valcke, 1991b).

The issue of the "structure of knowledge" has been debated from a variety of theoretical points of view : cognitive psychology, epistemology, philosophy, etc. At the more pragmatic level, the issue has also been of prime importance in applied sciences like instructional psychology, curriculum development theories and psychometry. 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 and Stein (1983).

It should be noted that our primary focus in using these theories originates from an information processing view on learning (Sternberg, 1985a & 1985b). The main reason for this is that we stress a dynamic approach towards the structure (knowledge acquisition) of knowledge, which is in particular advocated in

[1] A more elaborated version of the theoretical base of the knowledge profile dimensions can be found in : Dochy & Valcke (1991a). Validation of Knowledge Profile Dimensions : Looking for empirical Evidence. OTIC Research report 33. Heerlen : Ou-OTIC.

this view. If we summarize the variety of approaches, four main types of dimensions to structure knowledge can be conceptualized :

Content related dimensions
Educational dimensions
Epistemological dimensions
Item characteristic dimensions

As discussed in another publication (Dochy and Valcke, 1991), some of these dimension are of a hierarchical nature.

2.2 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 et. al., 1980) have some similarity in meaning. This is certainly the case for the studies by Letteri et. al. (1980, 1982). The concept 'profile' is derived from the practice, common in educational research, of plotting as a graph or profile the scores of a person as raw scores or as standardized scores (Keeves, 1988). In analyzing research findings, comparisons are made between persons or groups in terms of a set of measurements on specific related aspects. For each person or group a profile is obtained on a set of parameters. The comparison between profiles of persons is known by the generic term 'profile analysis'.

Figure 1 shows the relationship between some key concepts. A "dimension" is used to construct a knowledge profile. Each dimension represents an approach towards the structure of knowledge. The structure components are named "parameters".

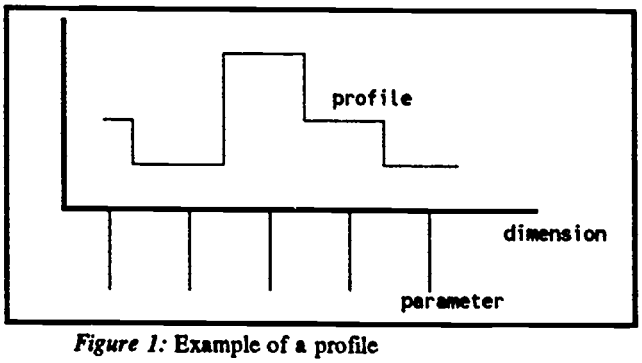

Figure 1: Example of a profile

From an instructional psychological point of view, knowledge profiles can give practical indications of student achievement and learning in order to direct the learning process. In a recent overview of student assessment, Wolf et. al. (1991) advocate this approach. According to these authors, there is a need for new educational psychometrics capable of answering the much changed question of educational achievement. These changes are the new premises, the multiple paths towards the prior knowledge state, more developmental oriented assessments and the ascertainment that students enter school with widely varying backgrounds. In our terms, we take account of these changes by trying to identify multiple components of the prior knowledge state by implementing prior knowledge state tests and by intending to use these tests as progress tests administered several times a year. In this context it is necessary to come to an agreement on the relevant parameters to describe student performance and it is critical to develop ways of looking at 'student profiles': " unless we develop these kinds of differentiated portraits of student performance within a domain, it is difficult to envision student assessment ever informing, rather than merely measuring, the educational process" (Wolf, et. al., 1991).

2.3 Overview of Knowledge Profile Dimensions

Only those dimensions/parameters are reviewed that have been retained after their discussion and analysis in our earlier publication "Validation of Knowledge Profile Dimensions : Looking for empirical Evidence".
If dimensions are based on a model or theory, only short details will be reported.
The first dimensions are classified according to common models of economics. Other dimensions are based on theories of knowledge representation, knowledge structure, learning theories, text representation models and psychometric theory.

2.3.1 Content Dimensions

Economics subdomains dimension

"Content" is a commonly used dimension to categorize domain knowledge. Classification based on the parameter 'subdomains' refers to the subdivision of the economics-domain into "subject matter blocks" that are standard within the science of economics. Our dimension structure is e.g. based on the curriculum structure of the University of Maastricht and reflects 9 parameters :

1. Reporting
2. Financing
3. Organization
4. Marketing
5. Macro-economics
6. Micro-economics
7. Public finances
8. International economic affairs
9. Behavioural and social sciences

Curriculum level 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). These levels are subsequent, but too broad to be supposed hierarchical.

1. First year level
2. Second year level

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

2.3.2 Cognitive Psychological Dimensions

Node relation dimension

Knowledge representation, as used in schema theories (Dochy and 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 in a statement. 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.

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

The "Node Relation" dimension is based on characteristics of the interrelations between propositions, called 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 and Bouwens, 1990). These arc parameters are not of a hierarchical nature.

2.3.3 Educational-Psychological Dimensions

The theoretical base of these two dimensions - i.e. behavioural and content dimension - is found in Component Display Theory (CDT, Merrill, 1983), Taxonomy theories (De Block, 1986 and Bloom, 1956) and Gagné's theoretical classification (1985).

Behavioural dimension

The known distinction between declarative and procedural knowledge is further operationalised at this stage into the parameters 'to know, to understand, and to apply'. These parameters are also perceived as equivalent to the concepts 'recognition, reproduction and production'. Items can be classified as measuring the appreciation, the recognition and the reproduction of information (declarative) or measuring production or applications (interpretative, convergent, divergent or evaluative production= procedural) (Keeves, 1988).

The three parameters do also correspond with taxonomic levels proposed by several educationalists as Bloom, Guilford, De Corte and De Block (cf. Keeves, 1988). Most researchers agree that these parameters are hierarchical in nature.

1. Know 2. Understand 3. Apply	1. Declarative 2. Procedural

Content dimension

Along the content dimension we differentiate five parameters : facts, concepts, relations, structures and methods. This is in accordance with e.g. the work of Guilford when he refers to product parameters (Keeves, 1988). These parameters are widely accepted as being hierarchical (Keeves, 1988).

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

Epistemological dimension

Based on the levels of knowledge representation of Brachman (1985), five parameters can be differentiated along a typical dimension. These parameters can also be considered as the most appropriate combinations of behaviour- and content levels, 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 behavioural and content level.

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

2.3.4 Item Characteristics Dimensions

Number of propositions dimension

A proposition is the smallest unit that can stand as a separate assertion which can be judged as true or false. In schema theories (Dochy and Bouwens, 1990), propositions or nodes have a core function in the structure of schemata. It is assumed that the amount of propositions determines the degree of structure needed to answer the item correctly. Three parameters have been identified in relation to this dimension :

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

Information level dimension

The "stem" of an item is the general information which is given and which must not be evaluated. This correct information precedes the questions 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 is larger than for simple items without a stem.

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

Representation level dimension

Following the classification used in the research of Boekaerts (1979), i.e. visual, verbal and symbolic representation, we distinguish four parameters along this dimension. These parameters are also closely related to the four content levels of Guilford's structure of intellect model: figural, symbolic, semantic (the verbal factor) and behavioural (nonverbal information) and the Twyman (1985) categories : verbal, pictorial and schematic.

Test-items are always based on textual information representation, but can be enhanced, enriched or documented with information of an other representation category :

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

2.4 A rationale for Differences between University Populations

As explained in the introduction 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 Open university.
Another approach goes beyond these surface variables and analyzes in more detail the prior knowledge state of the students opting for the Ou. The logical research question, which results from this approach is whether the prior knowledge state of the students, opting for this study context is different from students studying at regular universities.

The analysis of the prior knowledge state has been the major focus in a variety of research projects at the Open university (Centre for Educational Technology and Innovation). Among the important findings of these studies, we mention :

- Personal and contextual variables are no good "indicators" of the prior knowledge state.
- Subjective ratings of the prior knowledge state do not reflect the real prior knowledge state level.
- Components of the prior knowledge state can be identified along the content dimension (e.g. mathematics, optimal requisite knowledge, etc.).

As explained in the former parts of this text, the development of "knowledge profiles" has a large potential to describe in more detail "components" of the prior knowledge state. In the further part of this text, we will try to apply this new approach to the central question of this research : Is studying at a different University reflected in differences in the prior knowledge state ?

3 Research design

3.1 Hypotheses

Taking into account the theoretical base of the present study, the following main hypothesis can be stated :

> ***"Ou-students and RL-students are different in terms of the parameters along a variety of knowledge profile dimensions".***

Since up to 10 profile dimensions will be used, the main hypothesis can be split up into a set of 10 subhypotheses :
- Ou-students and RL-students have a different **economics subdomains** knowledge profile.
- Ou-students and RL-students have a different **curriculum** knowledge profile.
- Ou-students and RL-students have a different **curriculum accent** knowledge profile.
- Ou-students and RL-students have a different **node relation** knowledge profile.
- Ou-students and RL-students have a different **behavioural** knowledge profile.
- Ou-students and RL-students have a different **content** knowledge profile.
- Ou-students and RL-students have a different **epistemological** knowledge profile.
- Ou-students and RL-students have a different **representation level** knowledge profile.
- Ou-students and RL-students have a different **number of propositions** knowledge profile.
- Ou-students and RL-students have a different **information level** knowledge profile.

3.2 Research Instruments

As described above, a domain specific knowledge state test was administered to the research population. This test consists of 154 items. The test covers the whole domain of economics to be studied at university level in relation to the courses "Economics & Money".
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.

The particular characteristics of this test already suggest that the determination of its psychometric qualities might be a problem. 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 : $\alpha = .9302$.

But this high reliability level is marred by the fact that the test is very long (154 items); thus resulting rather easily in a high α-coefficient. Moreover, the test is not homogeneous (cf. the different profile dimensions specified above) what implies that basic assumptions to calculate the α-coefficient have been violated.

Table 1 :
σ-coefficients for the subdomains and curriculum accent dimension

Dimension/parameters	σ	N_{items}	m_σ
Reporting	.5739	18	
Financing	.6449	18	
Organization	.6922	18	
Marketing	.6292	18	
Macro-economics	.7069	25	.631
Micro-economics	.7420	25	
Public Finances	.5101	11	
International Economic affairs	.5543	11	
Behavioural & Social Sciences	.6287	10	
General economics & Business Administration	.9270	139	.686
Quantitative economics	.4467	15	

A solution to this problem might be to check the reliability of subparts of the test, making use of the knowledge profile dimensions. Calculation of α was repeated for two of these dimensions (course subtopics and curriculum accent), in order to be able to present a mean reliability score. The results of this procedure are summarized in table 1. To be able to judge the figures in a better perspective, the number of items each subgroup of items consists of is also given.
Mean α seems to be > .63. This reliability score is - taking into account the restricted number of items in certain subparts of the test - acceptable for our research purposes.

3.3 Research Population and Procedure

The test was administered to a sample of economics students studying at the Dutch Open university and the Maastricht University. This sample consisted of 626 students.

The domain specific knowledge state test was administered to a sample of Ou-students (N=91) and RL students (N=536). To obtain equal sample sizes, a random sample (N=91) was selected from the large RL-population of the Maastricht university.
The raw scores for the test items were recoded in order to gather a maximum of information in relation to mastery or non-mastery of the domain specific knowledge. After recoding[2], a general economics-score for the entire test was calculated.

In a next step, all items were classified along the dimensions discussed in part 2 of this text. The 154 items were analyzed - separately - by three researchers. In reviewing the items, the researchers attempted to classify each item on each one of the 10 dimensions. An inter-rater reliability was obtained > .8[**3]. If there was discussion in relation to the categorization of a specific item along a dimension, discussion resulted in a consensus on the final evaluation of the item.
Grouping the items along the knowledge profile dimensions helped to calculate specific subscores. To ease comparison of mean total subscores, the individual subscores have been calculated as %-scores.

[2] The normal scoring procedure for this test implies that students obtain +1 when their answer is correct; obtain 0 when they answer with ? and obtain -1 when their answer is wrong. In the recoding process, scoring for wrong answers was changed into a zero-score.

[3] * = $p \leq .05$ ** = $p \leq .01$

4 Discussion of the research results

4.1 General Results

Table 2 on the next page gives an overview of the mean scores and subscores for the entire test and the different regroupings of items along the 10 dimensions.

The name of each dimension is given in the first column. Next the names of the different parameters along the dimensions are recited, with - in the third column - the number of items that have been identified as exponents of this parameter.
A striking fact in the table is the large difference in the number of items that help to calculate the parameter-subscores. Some N_{items}-values are even problematic. For instance : the "Reason" parameter along the "Node Relation" dimension is represented by only two items, making this parameter less useful and weakening the validity of this dimension. This has to be taken into account when interpreting the analysis results.

The mean % score of the total research sample for each specific parameter is reported in the fourth column. The mean % scores for the different parameters in relation to each dimension show striking differences. The economics subdomains dimension presents for instance mean % scores varying from 17.97 % to 38.77 %. This suggests - at a first level - that some dimensions/parameters are helpful to indicate mastery or non-mastery of specific components of the prior knowledge state.

Next to the differences in mean scores, especially the large σ-values draw our attention. These large values are the result of the fact that the test measures " the prior knowledge state" of starting university students with a wide variety of prior experiences in relation to the topics assessed by the test.

Table 2 :
Overview of general results

DIMENSION	PARAMETERS	N_{item}	$m_{\theta\ item}$	σ
Economics Subdomains Dimension	Reporting	18	31.14	17.69
	Financing	18	29.15	17.68
	Organisation	18	38.00	21.07
	Marketing	18	36.77	19.61
	Macro-economics	25	22.97	16.58
	Micro-economics	25	24.62	18.42
	Public finances	11	30.47	20.69
	Intern. economics affairs	11	23.08	19.34
	Behavioural & social sciences	10	17.97	19.69
Curriculum Dimension	First year level	102	30.21	14.08
	Second year level	52	25.83	5.96
Curriculum Accent Dimension	General economics & B.A.	15	29.16	14.86
	Quantitative economics	139	24.84	14.88
Node Relation Dimension	Reason	2	26.37	32.69
	Initiate	8	25.34	19.95
	Consequence	58	29.66	15.02
	Manner	5	39.89	24.11
	Property	81	27.78	14.91
Behavioural Dimension	Know	24	29.37	16.23
	Understand	99	29.55	15.20
	Apply	31	25.65	14.85
Content Dimension	Facts	6	27.38	21.02
	Concepts	21	35.82	18.36
	Relations	32	29.60	15.81
	Structures	56	26.42	15.44
	Methods	39	27.74	15.82
Epistemological Dimension	Knowledge identification	15	30.95	17.67
	Knowledge conceptualisation	10	38.68	21.27
	Epistemological analysis	84	27.62	15.07
	Logical analysis	15	32.78	19.53
	Implementational analysis	30	25.42	14.94
Number of propositions Dim.	< 5	82	27.61	14.32
	> 5 < 10	44	13.79	06.99
	> 9	28	07.82	04.79
Information Level Dimension	Items with stem	105	31.07	15.74
	Items without stem	49	40.06	21.76
Representation Level Dimension	Textual-graphical	99	33.46	22.37
	Textual	9	29.78	15.08
	Textual-schematic	14	30.10	17.39
	Textual-symbolic	32	24.57	15.40
OVERALL ECONOMICS TESTSCORE		154	44.25	22.22

4.2 Profiles of Ou & RL Students : a first Analysis

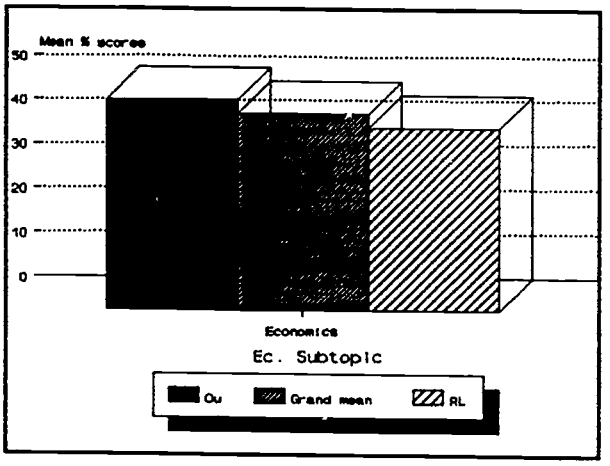

Figure 2 : Mean economics scores of Ou-students and RL

Fig. 2 depicts the differences in the mean overall test score of Ou-students and RL. This difference is not significant[4] ($F=3.747$, $p_F=.054$). This is consistent with our earlier research findings (Dochy and Valcke, 1991b). In these research reports the university setting was considered as a context variable, next to other personal variables, which was not helpful to predict differences in the prior knowledge state or was not helpful to clarify differences in between the student populations. But as also suggested in these earlier research reports (Dochy and Valcke, 1991) a more thorough analysis of the overall economics-score for the Prior Knowledge State-test can be helpful to reveal - nevertheless - specific (and significant) differences.

4.2.1 Economics Subdomains Dimension

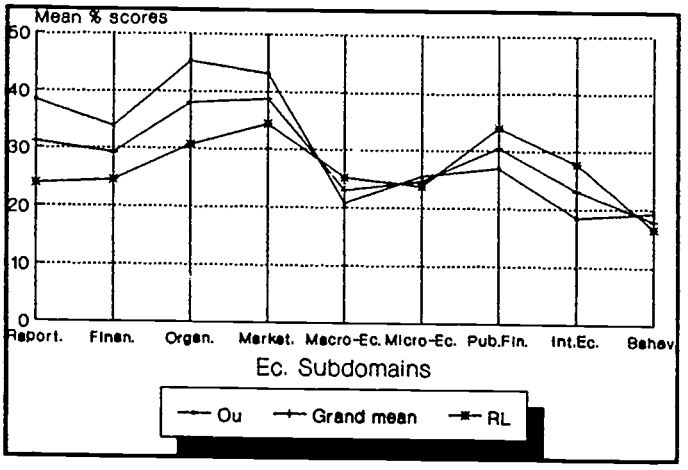

Figure 3 : Economics Subdomains knowledge profile

The data in fig. 3 reveal clear differences in the mean % scores of Ou- and RL-students for the different economics-subtopics. The mean % scores of Ou-students are higher for most subscores, with the exception of "macro-economics" and "public finances".

[4] The concept "significant" in this report refers to "statistically significant" results.

It is therefore interesting to test the significance of these differences in mean % scores[5]. This analysis reveals that the differences in mean %-scores of Ou- and RL-students are significant for the subscores "reporting", "finance", "organisation", "marketing" "public finance" and "international economics".

4.2.2 Curriculum Dimension

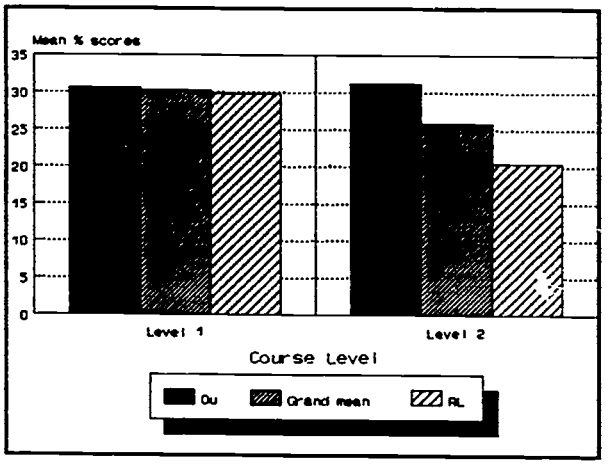

Figure 4 : Curriculum knowledge profile

As expected, the mean % scores for the level-2 items are lower for both sub-populations. It is normal that the prior knowledge state of these advanced level questions remains rather restricted.
For level-1 items there's no significant difference between Ou-students and RL students ($F=.126$, $p_F=.723$). Ou-students score higher than RL-students on level-2 items and this difference is statistically significant ($F=18.347$, $p_F=.000$).

4.2.3 Curriculum Accent Dimension

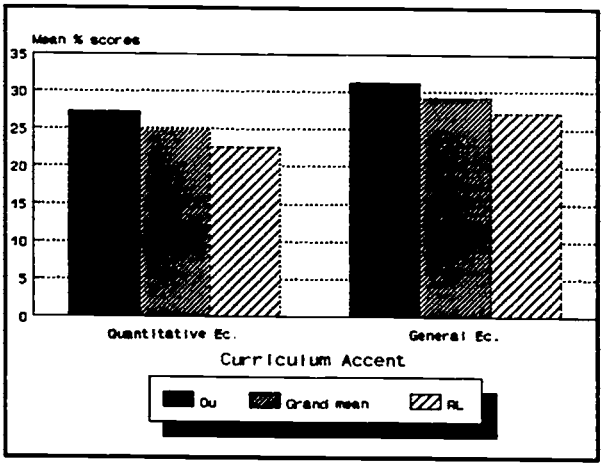

Figure 5 : Curriculum accent knowledge profile

[5] If we analyze the correlation matrix of the mean % scores for the different economics subtopics, we perceive some high intercorrelations. This has to be taken into account when comparing the mean % scores of the two student-populations. At first level, we neglect these correlations between the scores for the different economics-subtopics, to test the significance of the differences between the mean % scores by a univariate F-test. In part 4.3 of this text, we will take the intercorrelation between the subtopics into account when executing a multivariate F-test.

The curriculum accent profile shows that "general economics" mastery is higher than "quantitative economics" mastery. Also interesting is the fact that Ou-students have higher mean % scores than RL-students for "general" as well as "quantitative economics" mastery, although this difference remains non-significant.

4.2.4 Node Relation Dimension

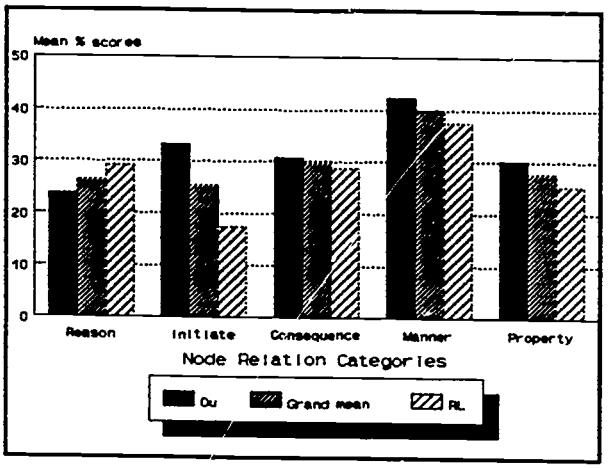

Figure 6 : Node relation knowledge profile

There is a difference between Ou- and RL-students in the mastery of all node relation categories. With the exception of the "relation" node category, Ou students score higher than RL-students. The biggest difference between the mean %-scores of Ou- and RL-students is observed in association with the "initiate" category. Only the latter difference is statistically significant ($F=33.693$, $p_F=.000$).

4.2.5 Behavioural Dimension

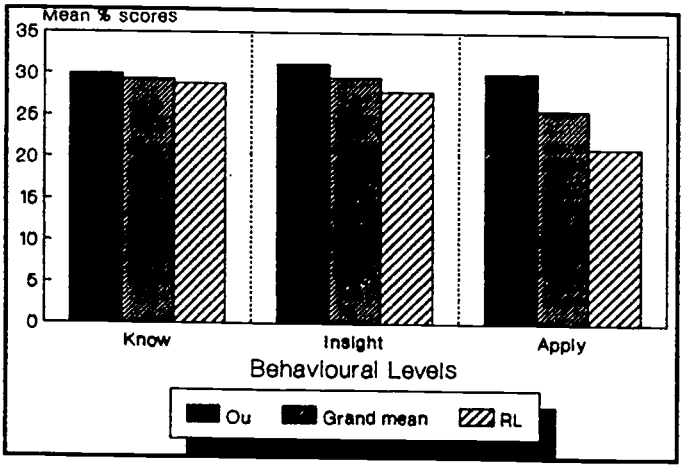

Figure 7 : Behavioural knowledge profile

It is found that there is a difference between Ou- and RL-students in the behavioural level knowledge profile. Typically we found that this difference is only manifest at the "apply" level. This difference between Ou- and RL-students is significant ($F=17.851$, $p_F=.000$).

4.2.6 Content Dimension

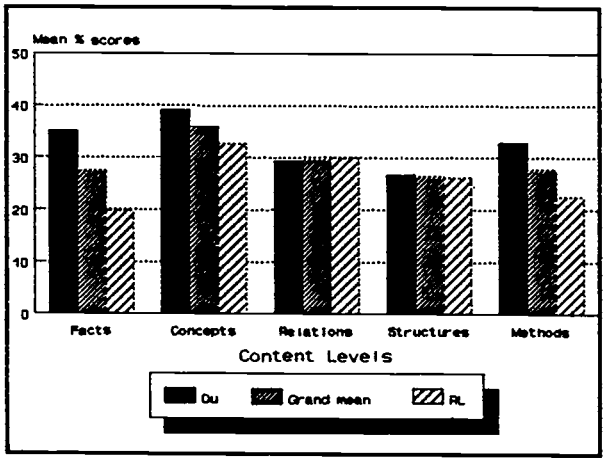

Figure 8 : Content knowledge profile

If we consider the "content level" knowledge profile we can conclude that for some categories there is a difference between Ou- and RL-students: Ou-students have a superior mastery of "factual" knowledge" ($F=27.260$, $p_F=.000$), "concepts" ($F=5.737$, $p_F=.000$) and "skills" ($F=21.146$, $p_F=.000$).

4.2.7 Epistemological Dimension

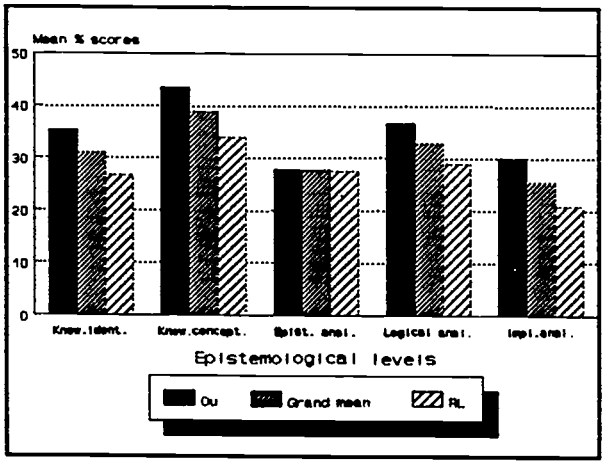

Figure 9 : Epistemological knowledge profile

In the epistemological knowledge profile we see again differences between Ou- and RL-students. With the exception of the epistemological analysis category, Ou-students always perform superior. The differences between the two groups are significant (Kident ($F=11.314$, $p_F=.001$); Kconcept ($F=9.400$, $p_F=.003$); Logical ($F=7.302$, $p_F=.008$); Implem ($F=18.451$, $p_F=.000$)).

4.2.8 Number of Propositions Dimension

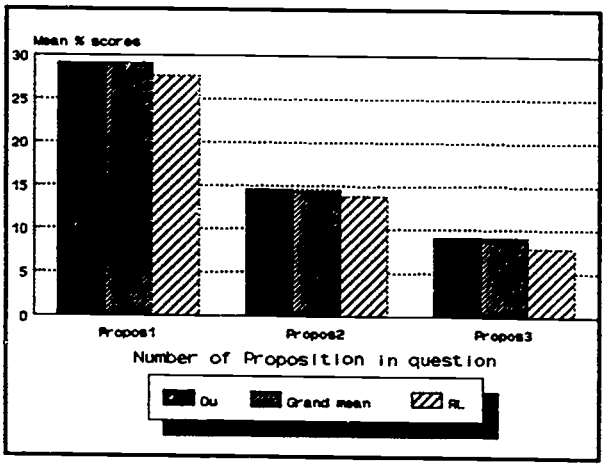

Figure 10 : Number of propositions knowledge profile

Items with a high number of propositions are more complex than items with a low number of propositions. It is typically that Ou-students perform better at all proposition-levels than RL-students. Only the difference at the highest level is significant ($F=8.135$, $p_F=.005$), which means that Ou-students deal better with complex items than RL-students.

4.2.9 Information Level Dimension

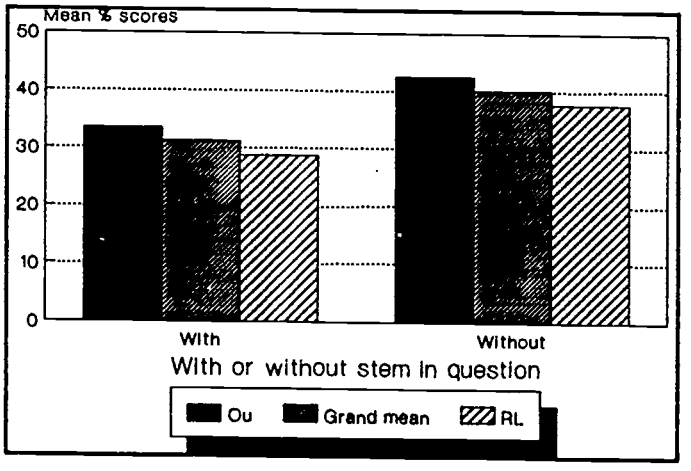

Figure 11 : Information level knowledge profile

Mastery of items without a stem seems to be slightly higher than mastery of items with a stem. This can be related to the findings in relation to the number of propositions. Items without a stem are based on a smaller amount of propositions and are therefore seemingly more easy to comprehend and to solve. Although Ou-students perform better in relation to both types of questions, these differences in mean %-scores are not statistically significant.

4.2.10 Representation Level Dimension

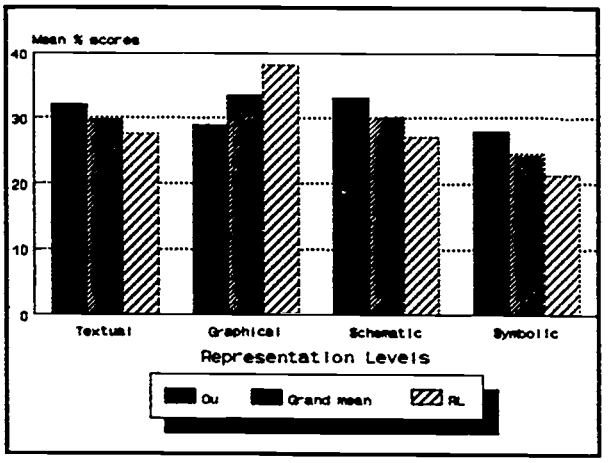

Figure 12 : Representation level knowledge profile

The mastery of representation levels suggests that RL-students are more able to solve questions based on graphical information. Ou-students seem to master questions, based on textual, schematic and symbolic information to a higher extent. With the exception of textual representation, these differences in mean %-scores are statistically significant (graphical $F=8.135$, $p_F=.005$, schematic $F=5.638$, $p_F=.019$, symbolic $F=8.795$, $p_F=.003$).

4.2.11 Intermediate conclusions

Although the overall prior knowledge state mean % score for the economics domain is not significantly different between the Ou- and the RL-student population, the knowledge profiles seem to be helpful to enlighten obvious differences in the complex composition of components of the prior knowledge state. Table 3 gives a summary of the analysis data of the univariate analysis of variance :

Table 3 :
Analysis of variance data of mean % scores of RL and Ou students

Dimension/parameter	Ou	RL	$F_{univ.}$	p_F
Overall economics score	47.42	41.09	3.747	.054
ES Report	39.40	23.87	36.753	.000
ES Finance	33.82	24.48	13.577	.000
ES Organ	45.30	30.71	24.664	.000
ES Market	43.16	34.37	9.574	.002
ES Macro	20.75	25.19	3.305	.071
ES Micro	25.49	23.74	.413	.521
ES Public	26.97	33.97	5.429	.021
ES Internat	18.48	27.67	10.833	.001
ES Behav	19.34	16.59	.886	.348
C Level1	30.59	29.84	.126	.723
C Level2	31.19	20.48	18.347	.000
CA Quant	27.18	22.49	4.605	.033
CA General	31.18	27.13	3.420	.066
NR Reason	23.63	29.12	1.288	.258
NR Initiate	33.24	17.45	33.693	.000
NR Consequence	30.60	28.72	.708	.401
NR Manner	42.20	37.58	1.674	.197
NR Property	30.16	25.40	4.740	.031
B Know	29.95	28.80	.226	.635
B Insight	31.21	27.88	2.197	.140
B Apply	30.10	21.20	17.851	.000
Co Factual	34.98	19.78	27.62	.000
Co Concept	39.04	32.60	5.737	.018
Co Relation	29.29	29.91	.069	.793
Co Structure	26.67	26.18	.046	.831
Co Skills	32.85	22.63	21.146	.000
E Kident	34.24	26.76	11.314	.001
E Kconcept	43.41	33.96	9.400	.003
E Episte	27.75	27.49	.014	.907
E Logical	36.63	28.94	7.302	.008
E Implem	29.96	20.88	18.451	.000
NP Propos1	29.01	26.20	1.765	.186
NP Propos2	14.55	13.03	2.158	.144
NP Propos3	9.08	6.57	13.303	.000
IL With stem	33.45	28.68	4.270	.040
IL Without stem	42.43	37.69	2.178	.142
RL Text	32.02	27.53	4.115	.044
RL Concret	28.82	38.10	8.135	.005
RL Scheme	33.12	27.08	5.638	.019
RL Symbolic	27.88	21.26	8.795	.003

4.3 Profile analysis

4.3.1 Profile analysis as an extension of multivariate analysis of variance

A univariate analysis of variance neglects the intercorrelations between the different parameters on the profile dimensions. These intercorrrelations are important (although not making the specific variables redundant) and can be explained at the theoretical level as illuminated elsewhere (Dochy and Valcke, 1991a). Therefore, a multivariate analysis of variance is needed to refine our analysis and to look for more conclusive information about the differences in the prior knowledge state between Ou-students and RL-students. A multivariate analysis can take these intercorrelations into account. Profile analysis is an extension of multivariate analysis and is especially appropriate and helpful to evaluate the parameter structure in relation to each profile dimension when comparing populations. Therefore, a profile analysis will be performed on the complex of parameters in relation to each dimension. Several tests are available in profile analysis. Of principal interest - for our purposes - is the "parallelism" test which help to answer the

question whether the profiles of two subpopulations are parallel or not. If certain dimensions are helpful to detect non-parallel profiles, it might be interesting to know what parameter along the dimension does contribute most to these significant differences. Therefore, for non-parallel profiles, the analysis will be extended with a discriminant analysis (also called, the "level" test). At the theoretical level - as suggested in part 4.2 of this text - also the "flatness" test might be relevant, since this test controls the similarity of responses for the different parameters along a dimension, independent of groups or subgroups. An answer to this question helps to support the validity of the different dimensions since the results indicate whether or not the dimensions/parameters are helpful to specify differences in the mastery of different components of the prior knowledge state.
The grouping variable in our analysis is "University" (Ou- or RL-student). SPSS-PC+ MANOVA was used for the analysis.

4.3.2 Control of underlying assumptions

Profile analysis implies that some basic assumptions are met :

- Data screening revealed no missing data.
- Sample sizes are equal for both subpopulations (N=91), so no special difficulties are expected. Moreover, only one independent variable is used.
- Attention has to be paid to a test of the homogeneity of the variance-covariance matrices. The evaluation of the homogeneity of variance-covariance matrices is based on the Cochrans and the Bartlett-Box F test. No problems are expected taking into account the equal sample sizes (91/91) and the satisfactory size of the samples.
- Multicollinearity is tested with the Bartlett test of sphericity.
- To evaluate assumptions about multivariate normality, boxplots of the mean submeasures for each dimension have been screened. In evaluating multivariate normality of the distribution of the mean %-scores, it is to be mentioned that the σ-values are very high, indicating a wide dispersion of the scores. This is to be expected, since the test measures " the prior knowledge state".

Table 4 summarizes the data in relation to the evaluation of the homogeneity of variance-covariance matrices and the multicollinearity test. In relation to several dimensions, the assumption in relation to the homogeneity of the variance-covariance is violated ("subtopics" profile: micro-economics, "mode relation": initiate, "behavioural level": apply, "content level": methods, "epistemological level": skills, "representation level": symbolic representation). In our profile-analysis, this will be taken into account by using Greenhouse-Geisser and Huynh-Feldt adjustments to these univariate violations of homogeneity of variance-covariance.
The Bartlett test of sphericity is significant in all cases, which means that the variables are highly intercorrelated. Although the p-values are very small, the SPSS-MANOVA-PC+ procedure protects against instability caused by multicollinearity by excluding variables from the analysis with too low tolerance levels[6]. The fact, the MANOVA-procedure was never halted during execution indicates that multicollinearity did not cause problems.

[6] Tolerance level = 1 - SMC (squared multiple correlation of each variable).

Table 4 :
Analysis data in relation to multicollinearity and homogeneity of variance-covariance matrices.

	Homogeneity of Variance		Multicollinearity
	Cochran C	Bartlett-Box F	Bartlett test of sphericity
Report	.61885 (p=.023)	5.20529 (p=.023)	
Finance	.60009 (p=.056)	3.66013 (p=.056)	
Organ	.55177 (p=.326)	.96473 (p=.326)	
Market	.56871 (p=.191)	1.70612 (p=.192)	
Macro	.57777 (p=.139)	2.19197 (p=.139)	987.410 (p=.000)
Micro	.67642 (p=.001)	11.90118 (p=.001)	
Public	.53878 (p=.462)	.53878 (p=.426)	
Internat	.52399 (p=.650)	.52399 (p=.650)	
Behav	.53235 (p=.540)	.37547 (p=.540)	
Level1	.53632 (p=.491)	.47339 (p=.492)	
Level2	.50285 (p=.957)	.00290 (p=.957)	183.397 (p=.000)
Quant	.59842 (p=.060)	3.53665 (p=.060)	
General	.54955 (p=.347)	.88348 (p=.347)	104.486 (p=.000)
Reason	.62661 (p=.015)	5.93145 (p=.015)	
Initiate	.64513 (p=.005)	7.87839 (p=.005)	
Conseq	.50573 (p=.914)	.01173 (p=.914)	487.276 (p=.000)
Manner	.53602 (p=.495)	.46559 (p=.495)	
Property	.57929 (p=.131)	2.27862 (p=.131)	
Know	.55883 (p=.264)	1.24778 (p=.264)	
Insight	.50539 (p=.919)	.01038 (p=.919)	390.814 (p=.000)
Apply	.69279 (p=.000)	14.40809 (p=.000)	
Factual	.61660 (p=.025)	5.00511 (p=.025)	
Concept	.50548 (p=.917)	.01076 (p=.917)	
Relat	.52711 (p=.608)	.26345 (p=.608)	644.228 (p=.000)
Struct	.53813 (p=.470)	.52216 (p=.470)	
Methods	.65809 (p=.002)	9.42804 (p=.002)	
Kident	.59030 (p=.084)	2.98114 (p=.084)	
Kconcept	.52655 (p=.615)	.25267 (p=.615)	
Episte	.51628 (p=.758)	.09499 (p=.758)	609.366 (p=.000)
Logical	.52689 (p=.611)	.25927 (p=.611)	
Implem	.69798 (p=.000)	15.26470 (p=.000)	
Propos1	.54853 (p=.357)	.84702 (p=.358)	
Propos2	.53859 (p=.465)	.53481 (p=.465)	459.793 (p=.000)
Propos3	.58282 (p=.115)	2.49016 (p=.115)	
Withs	.56207 (p=.238)	1.39005 (p=.239)	
Without	.52777 (p=.599)	.27649 (p=.599)	239.921 (p=.000)
Text	.53921 (p=.457)	.55211 (p=.458)	
Concret	.50404 (p=.939)	.00584 (p=.939)	414.124 (p=.000)
Scheme	.56057 (p=.250)	1.32332 (p=.250)	
Symbol	.67571 (p=.001)	11.79832 (p=.001)	

To evaluate **multivariate normality** box-plots of the mean % scores have been analyzed. Figure 13 presents e.g. a box-plot of the scores of Ou- and RL-students for the subtopic "marketing" on the subtopic-profile dimension. The * identifies the median and the box contains the middle 50% of the values. The lines emanating from the box extend to the smallest and largest observations in the subgroups that are less than one interquartile range from the end of the box. Points outside this range are marked with O (outliers) or even E (Extremes) if more than 1.5 interquartile distances away from the box.

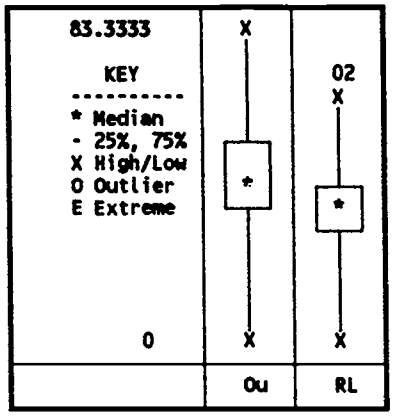

Figure 13 : Box-Plots

Analysis of the box-plots for each variable in relation to each profile dimension reveal that there are outliers and extremes, but that their number remains restricted. Moreover, outliers are considered part of the particular distribution of our data. They are properly part of the population from which we intend to sample. Since the data reflect mastery of " the prior knowledge state" it is no surprise that the distribution of the data set does not reflect the "ideal" normal distribution.

In general we can conclude that assumptions are met in order to execute a profile analysis on the research data available. Only in interpreting the analysis results in relation to the above mentioned categories we will have to take care.

4.3.3 Profile Analysis : Parallelism Test

Table 5 presents an overview of the results for the parallelism test. This helps to answer the question whether the two different student groups have parallel or non-parallel profiles. This is commonly known as the test of parallelism and is the primary question addressed by profile analysis[7]. In relation to each profile dimension, Wilk's Lambda (λ) was calculated and p-level determined. In the results table, Wilk's λ is not reported in relation to four dimensions (marked with *). This is because these dimensions only contain two variables; in these cases a test of significance for Hoteling's T2 using the unique sums of squares was calculated, checking the interaction of the independent variable (student type) and the two dependent variables on the specific dimensions.

Table 5 :
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
Behavioural	.8891	.000
Content	.6664	.000
Epistemological	.7474	.000
Information Level*	00.00*	.984
Number of Propositions	.9798	.162
Representation Level	.8293	.000

The data in table 5 are helpful to detect specific significant differences between Ou- and RL-students. The intermediate conclusion of non-significant differences between Ou-students and RL-students, based on analysis of the overall economics-score, can again be revisited by the refined breakdown of the profile analysis results.
There are 7 knowledge profile dimensions which are helpful to illuminate significant differences between both student populations.

4.3.4 Profile Analysis : Discriminant Analysis

As mentioned in the introduction to our profile analysis a further analysis of non-parallel profiles can help to identify those parameters along the specific dimensions that contribute most to the differences between the two subpopulation (RL and Ou)[8]. In table 6, the results of this discriminant analysis are reported. Wilk's λ can in this context be interpreted as the proportion of variability not explained by the group differences. In the fourth column of the table, we derived from this value the proportion of variability explained ((1-λ) * 100) by the group differences resulting from the independent variable "University".

Table 6 :
Results of the discriminant analysis

Profile Dimension	Wilk's λ	p	% explained
Economics Subdomains	.54356	.000	46 %
Curriculum Dimension*	.80072	.000	20 %
Node Relation	.75485	.000	25 %
Behavioural	.84778	.000	15 %
Content	.63223	.000	37 %
Epistemological	.71453	.000	28 %
Representation Level	.79784	.000	20 %

[7] When using profile analysis as a substitute for univariate repeated measures ANOVA, the parallelism test is the test of interaction.

[8] Of course, the discriminant analysis is restricted to the non-parallel profiles.

The discriminant analysis can be extended by calculating structure coefficients[9] to determine the discriminatory power of the separate parameters along a knowledge profile dimension. The results of this analysis are found in table 7.

Table 7 :
Overview of structure coefficients

Dimension	Parameter	Structure coeff.
Economics Subdomains	Reporting	.493
	Financing	.300
	Organization	.404
Curriculum Dimension	Level2	.640
Node Relation	Initiate	-.759
	Property	-.285
Behavioural	Apply	.743
Content	Factual	.510
	Methods	.449
Epistemological	Implem. An.	-.507
	Kident	-.397
Representation Level	Textual-symbolic	-.439
	Textual-graphical	.422

A structure coefficient indicates the correlation between a parameter and the discriminant function. High values indicate important discriminant effects. Table 7 demonstrates that some parameters have structure coefficients up to > .5 . If we combine these results with the dimensions relevant to a statistical significant degree to differentiate between populations, we can conclude that the two university populations can especially be differentiated along the following two knowledge profile dimensions : the content level dimension and the epistemological level dimension.

4.3.5 Profile Analysis Results : Flatness Test

Is the mastery of the prior knowledge state as defined by the parameters along a dimension different, independent of the groups (a within-subjects main effect) ? In other words, do students master the prior knowledge state in a similar way as defined by the different parameters along a dimension ? This question is especially relevant for parallel profiles, since in non-parallel profiles at least one parameter is not flat; nevertheless also the results in relation to non-parallel profiles are reported.

[9] Since the subvalues on each profile dimension are highly intercorrelated, we cannot use raw or standardized discriminant function coefficients. The highly correlated variables "share" the discriminants weights. It is safer to base our interpretation on the structure coefficients which are less likely to be influenced by these intercorrelations.

Table 8 :
Results of the flatness test in profile analysis

DIMENSION	Wilks λ or F	p_λ or p_F
Economics Subdomains	.38827	.000
Curriculum Dimension*	34.14*	.000
Curriculum Accent*	23.36*	.000
Node Relation	.69421	.000
Behavioural	.83300	.000
Content	.63005	.000
Epistemological	.58030	.000
Number of Propositions	.18886	.000
Information Level*	111.54	.000
Representation Level	.73745	.000

If the flatness test is non-significant, then the profiles are not helpful to clarify or detect differences in the mastery of different components of the prior knowledge state. The results of the flatness test are therefore also of relevance to determine the validity of the knowledge profile dimensions.
The results of the flatness test are found in table 8. For each dimension Wilk's λ has been calculated, with the exception of the three dimension where only two parameters are available along the dimension; there the F-value is reported (marked with *).

All dimensions result in non-flat knowledge profiles. This implies that all dimensions are helpful to identify a specific structure in the mastery of the prior knowledge state. Following this structure, the mastery of certain components[10] of the prior knowledge state is better than for other components.

5 Conclusions

In this text, we attempted to analyze the prior knowledge state of two specific university subpopulations, studying a multifunctional course. In the present study, the overall economics score was not significantly different between both university populations. But in this research, special attention was paid to a further elaboration of this general economics-score by grouping items along a variety of knowledge profile dimensions. After outlining - in short - the theoretical base of these dimensions, we focused on the application of these dimension to compare the knowledge profiles of the two university populations. A profile analysis (parallelism test and discriminant analysis) could help to reveal specific significant differences between the profiles of both student populations. Up to seven of the ten knowledge profile dimensions proved to be of relevance. Especially the "content dimension" and the "epistemological dimension" were helpful to describe these differences.
A further extension of our profile analysis (flatness test) helped to induce further evidence to support the validity of the knowledge profile dimensions.
The present study is of importance since we succeeded in defining and operationalising a new and promising approach towards the analysis of the prior knowledge state. It is foreseen that in situations where there are significant differences between the prior knowledge state of specific subpopulations, the profile dimension 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.

[10] The concept "components" refers to this subpart of the prior knowledge state that can be isolated in connection to a specific parameter along a knowledge profile dimension.

6 References

Ausubel, D.P. (1968). *Educational Psychology: a cognitive view.* New York: Holt, Rinehart and Winston.

Bloom, B.S. et. al. (1956). *Taxonomie of educational objectives. Handbook I: Cognitive domain.* New York, Longmans, Green.

Boekaerts, M. (1979). *Towards a theory of learning based on individual differences.* Ghent, Communication and Cognition.

Brachman, R.J., Schmolze, J.G., (1985). An overview of the KL-ONE Knowledge Representation System. *Cognitive Science,* april, 171-216.

Clancey, W.J. (1983). The epistemology of a rule-based expert system - a framework for explanation. *Artificial Intelligence,* 20, 215-251.

Dochy, F.J.R.C. (1992). *Assessment of prior knowledge as a determinant for future learning: the use of prior knowledge state tests and knowledge profiles.* Utrecht/London: Lemma B.V. Jessica Kingsley Publishers.

Dochy, F.J.R.C., Bouwens, M.R.J. (1990). *Schema theories as a base for the structural representation of the knowledge state.* Heerlen. Centre for Educational Technology and Innovation, Research Report 18.

Dochy, F.J.R.C. & Valcke, M.M.A. (1991a). *Validation of knowledge profile dimensions : looking for empirical evidence.* OTIC research report nr. 33. Heerlen : Ou-OTIC.

Dochy, F.J.R.C. & Valcke, M.M.A. (1991b). *Are personal and contextual variables good indicators of expertise ? A study of subject-oriented expertise in an economics course.* Submitted for publication.

Dochy, F.J.R.C. & Valcke, M.M.A. (1991). *Are economics and law students different?* An exploratory study of the impact of expertise. Submitted for publication.

Duffy, T.M., Waller, R. (1985) (Eds.). *Designing usable texts.* Orlando: Academic Press.

Eisner, E. (1985) (Ed.). *Learning and teaching the ways of knowing.* Chicago: The university of Chicago Press.

Gagné, E.D. (1985). *The cognitive psychology of school learning.* Boston/Toronto: Little, Brown and Company.

Graesser, A.C. (1981). *Prose comprehension beyond the word.* New York: Springer-Verlag.

Groot, A.D. de (1946). *Het denken van den schaker.* Amsterdam: Noord-Hollandse Uitgeversmaatschappij.

Keeves, J.P. (Ed) (1988). *Educational research, methodology and measurement: an international handbook,* Oxford/New York: Pergamon Press.

Letteri, C.A. (1980). Cognitive profile: basic determinant of academic achievement. *The Journal of Educational Research,* 4, 195-198.

Letteri, C.A., Kuntz, S.W. (1982). *Cognitive profiles: examining self-planned learning and thinking styles.* Paper presented at the Annual American Educational Research Association Meeting, New York City, March 19-23.

Madaus, G.F., Woods, E.N., Nuttal, R.L. (1973). A causal model analysis of Bloom's taxonomy. American *Educational Research Journal*, 10, 253-263.

Mayer, R.E. (1979). Twenty years of research on advance organizers. *Instructional Science*, 8, 133-167.
Mc Daniel, E. (1991). *Levels of cognitive complexity: a framework for the measurement of thinking.* Paper presented at the annual meeting of the AERA, Chicago.

Merrill, M.D. (1983). Component display theory. In Reigeluth, C.M. (Ed.). *Instructional-design models: an overview of the current status.* Hilldale, N.J.: Erlbaum.

Reigeluth, C.M., Stein, F.S. (1983). The elaboration theory of instruction. In Reigeluth, C.M. (Ed.). *Instructional-design models: an overview of the current status.* Hilldale, N.J.: Erlbaum.

Sternberg, R. (1985a). *A triarchic Theory of Human Intelligence.* Cambridge : Cambridge University Press.

Sternberg, R. (1985b). *Human Abilities : An Information Processing Approach.* New York : Freeman.

Tabachnick, B.G., Fidell, L.S. (1989). *Using multivariate statistics.* New York: Harper & Row.

Twyman, M. (1985). Using pictorial language: a discussion of the dimensions of the problem. In Duffy, T. M., Waller, R. (Eds.). *Designing usable texts.* Orlando: Academic Press.

Valcke, M.M.A. & Dochy, F.J.R.C. (1991). *Analysis of the quality and impact of expertise in economics.* OTIC-research report 26. Heerlen : Ou-OTIC.

Wolf, D., Bixby, J., Glenn, J., Gardner, H. (1991). To use their minds well: investigating new forms of student assessment. *Review of Research in Education*, 17, 31-74.