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ABSTRACT

This study sought to examine the nature and dimensions of prior knowledge among undergraduates in an economics course at the Open University of the Netherlands (OuN). A total of 22 law and 55 economics students enrolled in two economics courses were given a 154-item domain-specific knowledge test, which was then analyzed independently by three researchers. The researchers attempted to classify each of the 154 items on each of 10 dimensions (curriculum level, curriculum accent, node relation, behavioral, content, epistemological, number of propositions, information level, and representation level). The results of the analysis indicated that although different dimensions helped to differentiate between law and economics students, the different dimensions were not helpful in identifying more specific and significant contrasts between both student groups. The study also found that the grouping variable "diploma type" was not able to differentiate between levels of mastery of the prior knowledge state. It is foreseen that in situations where there are significant differences between the prior knowledge state of specific subpopulation, the dimensions might be helpful to detect the strengths and weaknesses of the students involved.

Knowledge Profiles of Economics and Law Students: an In-depth Analysis of the Prior Knowledge State

F.J.R.C. Dochy

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Centre for Educational Technology and Innovation
Open University

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1 Introduction

There is no doubt that the prior knowledge state is playing a major role in the learning process of students. In our recent work (Valcke and Dochy, 1991; Dochy and Valcke, 1991b), the analysis of the quality and impact of the prior knowledge state has been a major focus. Several instruments have been developed to measure the prior knowledge state, especially within the domain of economics. In analyzing the prior knowledge state, we did especially focus on the structure of the prior knowledge state along a content dimension.
In this report we report a study which supports the development of 'knowledge profiles' as an assessment tool in educational practice to direct future learning.

In the theoretical part of this text, we discuss - in short - our 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 second part of this text, these dimensions are used to analyze the knowledge profiles of economics and law students. The results help to detect differences in the mastery of components of the prior knowledge state between both student populations and might 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 deal with the prior knowledge state showed that one should take account different components of the prior knowledge state (Dochy and Valcke, 1991). 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 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 (Dochy, 1992).

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, models and (Ausubel, 1968, de Groot, 1946, Mayer, 1979, Reigeluth and Stein, 1983).

[1] A more elaborated version of the theoretical base of the knowledge profile dimensions can be found in : Dochy & Valcke (1991a). OTIC.

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

Content related dimensions
Cognitive-Psychological dimensions
Educational-Psychological dimensions
Item Characteristics dimensions

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., 1982) 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, consisting of several parameters, represents an approach towards the structure of knowledge.

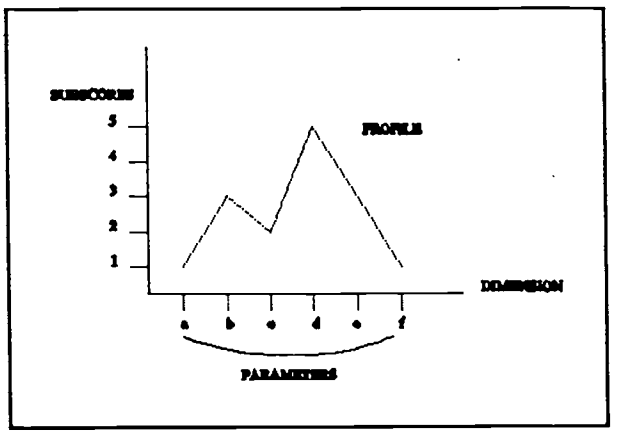

Figure 1: Example of a profile

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 a new brand of educational psychometrics capable of answering the much changed questions 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" (Dochy and Valcke, 1991a).
If dimensions are based on a model or theory, only short details will be reported. We will shortly report on the models or theories on which dimensions are based. The first dimensions are classified according to common models of economics. Other dimensions are based on theories on knowledge representation and on knowledge structure, learning theories, text representation models and psychometric theory.

2.3.1 Content related dimensions

Economics subdomains dimension

"Content" is one of the most exercised dimensions to categorize domain knowledge. The classification based on the parameter 'subdomains' refers to the subdivision of the economics-domain into "subject matter blocks" that are common within the science of economics. Our dimension structure, as implemented in the curriculum structure of the University of Maastricht, contains nine 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, a statement that refers to an ongoing state in the physical or social world), Physical Event (PE, a statement that refers to a state change in the physical or social world), Internal State (IS, a 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, a statement that refers to an achieved or unachieved state that a person wants) and Style (S, a 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 hierarchical in 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), Taxonomic theories (De Block, 1986 and Bloom, 1976) 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 of a hierarchical nature.

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

Content dimension

Along the content dimension we differentiate between 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 also 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 and Schmolze (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 dimension 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 dimensions are considered as hierarchical since they are a combination of the hierarchical behavioural and content dimension.

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.

Since the spatial and logical distance between the general information part of an item and the question part is larger in items with a stem than for items without a stem, the difficulty level of the former is expected to be higher.

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 the intellect: 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 The prior knowledge state of economics students (ES) and law students (LS)

The research population, as explained in the next paragraph, involved both economics an law students. Earlier research (Dochy and Valcke 1991; Dochy and Valcke, 1991b; Wagemans, Valcke and Dochy, 1991) helped to put forward the following conclusions :

- single variables, such as diploma type (e.g. economics, law), are not good indicators of the prior knowledge state;
- ES and LS are different in relation to specific components of the prior knowledge state;
- there is a trend that ES perform better that LS, but this difference is not statistically significant.

In the next part of this text, the 'knowledge profiles', discussed earlier, will be used as an assessment tool to compare in greater detail differences among the two student populations.

3 Research design

3.1 Hypotheses

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

"Economics students (ES) and Law students (LS) are not different in terms of the variables 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 :

- ES and LS are not different in terms of the economics subdomain knowledge profile.
- ES and LS are not different in terms of the curriculum knowledge profile.
- ES and LS are not different in terms of the curriculum accent knowledge profile.
- ES and LS are not different in terms of the node relation knowledge profile.
- ES and LS are not different in terms of the behavioural knowledge profile.
- ES and LS are not different in terms of the content knowledge profile.

- ES and LS are not different in terms of the epistemological knowledge profile.
- ES and LS are not different in terms of the representation level knowledge profile.
- ES and LS are not different in terms of the number of propositions knowledge profile.
- ES and LS are not different in terms of the information level knowledge profile.

3.2 Research instruments

A domain specific knowledge state test (PKS) 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" and "Balance sheet, Profit and Loss Account and Administrative Procedures". 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.
Characteristics of the test suggest that the determination of certain 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 since the test has been developed by a team of domain experts.

Table 1 :
α-coefficients for the course subtopics and curriculum accent dimensions and mean α-coefficients

PARAMETERS	α	N_{items}	m_α
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	
Intern. economic affairs	.5543	11	
Behavioural & social sciences	.6287	10	
General economics & B.A.	.9270	139	
Quantitative economics	.4467	15	.686

On the other hand, determining the reliability of the test induces some specific problems. If we calculate the alpha-coefficient, the test can be considered as 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. More important, calculation of the α-coefficient supposes the test to be homogeneous. Mostly tests are tests are homogeneous at the content level. The delineation of the knowledge profile dimensions above, indicates that this basic assumption to calculate the α-coefficient has been violated. 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. After reorganising the test into more homogeneous subparts, α-coefficient and a mean α-coefficient was calculated. 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

3.3.1 Research population and sample size

The research population consisted initially of 91 students. This number of students resulted from a 200 students containing, much bigger random sample, who were invited to participate in the project after subscribing for the course "Economics & Money" or "Balance sheet, Profit and Loss Account and Administrative Procedures" at the Dutch Open University (OU). The two courses are part of the compulsory program of different diploma lines, such as "Dutch Law" and "Economics". When administering the test to the students additional information was gathered in order to define of each student his diploma intentions. This helped to divide the research population sample into three groups : 55 economics students (ES) and 22 law students (LS) and a third group consisting of 14 students following other or undefined diploma lines. The latter group of students was withdrawn from the research sample. Final sample size was therefore 77 students.

3.3.2 Research procedure

The domain specific knowledge state test was administered to the sample of Ou-students. 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 compare the mean total subscores, the individual subscores have been calculated as %-scores.

4 Research results and discussion

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[4], named 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. 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 sometimes striking differences. The subtopic dimension presents for instance mean % scores varying from 18.3 % to 44.37 %. This suggests - a first level - that some dimensions/parameters can help to indicate mastery or non-mastery of 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 students with a wide variety of prior experiences in relation to the topics assessed by the test.
Another striking fact is the large difference in the number of items that help to calculate the parameter-subscores. Some N_{item}-values are even problematic. The "Reason" parameter along the "Node Relation"

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

dimension is e.g. 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 results of the analysis.

Table 2 :
Overview of general results

DIMENSION	*PARAMETERS*	N_{item}	$m_{\%\ item}$	σ
Economics subdomains	Reporting	18	38.31	18.28
	Financing	18	33.26	18.96
	Organization	18	44.37	21.15
	Marketing	18	42.78	21.12
	Macro-economics	25	21.35	18.52
	Micro-economics	25	26.13	22.37
	Public finances	11	26.56	21.51
	Intern. economics affairs	11	18.30	20.09
	Behavioural & social sciences	10	19.61	20.29
Curriculum level	First year level	102	30.49	15.08
	Second year level	52	31.22	17.74
Curriculum accent	General economics & B.A.	15	27.01	16.22
	Quantitative economics	139	31.14	16.14
Node relation parameters	Reason	2	22.73	28.73
	Initiate	8	32.14	21.11
	Consequence	58	30.47	15.95
	Manner	5	42.60	23.47
	Property	81	30.25	16.33
Behavioural level	Know	24	29.55	17.86
	Understand	99	31.26	15.91
	Apply	31	30.00	16.83
Content level	Facts	6	35.50	22.52
	Concepts	21	38.47	19.08
	Relations	32	29.34	16.14
	Structures	56	26.97	16.59
	Methods	39	32.40	17.19
Epistemological	Knowledge identification	15	34.63	19.38
	Knowledge conceptualisation	10	43.25	20.93
	Epistemological analysis	84	27.94	16.04
	Logical analysis	15	35.84	19.68
	Implementational analysis	30	29.91	17.00
Number of propositions	< 5	82	29.08	15.66
	> 5 < 10	44	14.44	07.49
	> 9	28	09.05	05.13
Information level	Items with stem	105	33.39	17.18
	Items without stem	49	42.41	23.16
Representation level	Textual-graphical	99	32.00	16.27
	Textual	9	29.00	22.74
	Schematic	14	32.65	18.41
	Symbolic	32	27.84	17.85
ECONOMICS TESTSCORE		154	47.34	24.14

4.2 Profiles of ES & LS : a first analysis

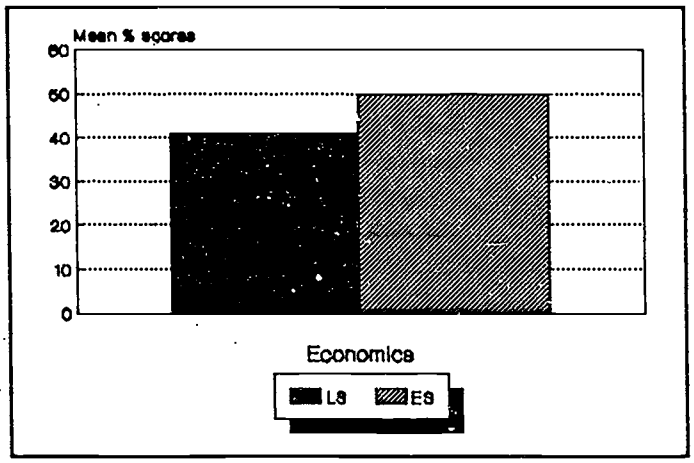

Figure 2 : Mean economics scores of ES and LS

Figure 2 depicts the differences in the mean % scores of ES and LS for the overall economics score. This difference is - although nearly 10% - not statistically significant ($F=2.124$, $p_F=.149$) as expected. But as suggested in earlier research reports (Dochy and Valcke 1991, p. 11), a more thorough analysis of the overall economics-score for the PKS-test can be helpful to reveal specific (and significant) differences.

4.2.1 Economics subdomains dimension

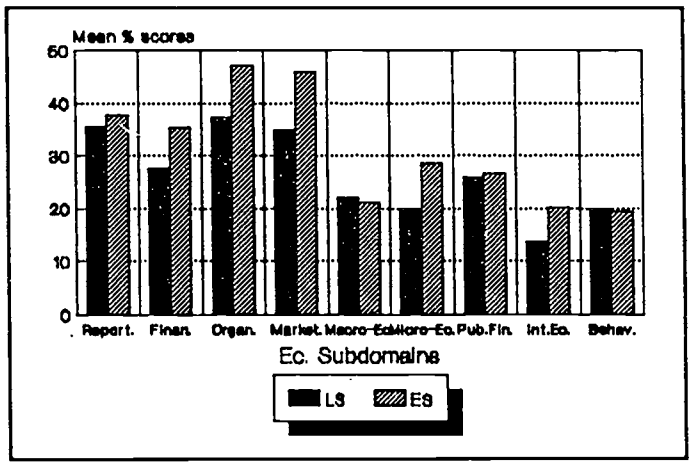

Figure 3 : Economics Subdomains knowledge profile

The data in figure 3 reveal clear differences in the mean scores of economics and law students for the different economics-subdomains. The mean % scores of ES are higher for most subscores, with the exception of "macro-economics", "public finances" and "behavioural & social sciences". If we neglect the interrelations between the different economics-subdomains, we can test the significance of the differences between the mean-scores by a univariate F-test[5]. This analysis of variance reveals that the differences in mean % scores of ES and LS are not significant. The most important p_F-value is obtained in relation to "Marketing" ($F=4.554$, $p_F=.036$).

[5] In part 5.3 of this text, we will take the intercorrelation between the subdomains into account when executing a multivariate analysis of variance. A summary of univariate analysis of variance results is given in part 4.2.11.

4.2.2 Curriculum level dimension

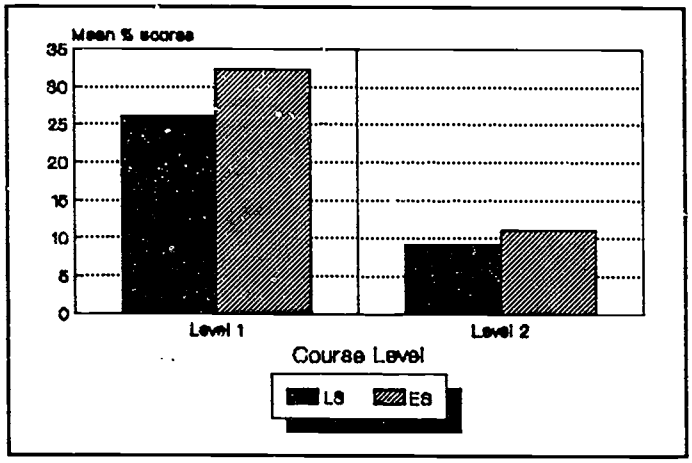

Figure 4 : Curriculum knowledge profile

As expected, the mean score for the level-2 items are lower for both sub-populations. It is normal that the prior knowledge state of these advanced level questions is restricted.
Although economics-students always obtain higher mean % scores for both course levels, these differences are not statistically significant.

4.2.3 Curriculum accent dimension

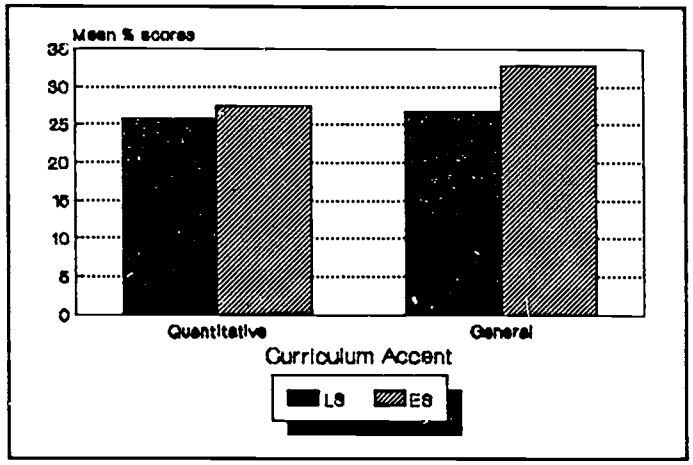

Figure 5 : Curriculum accent knowledge profile

The curriculum accent profile shows that "General economics & Business Administration" mastery is higher than "Quantitative economics" mastery. Also interesting is the fact that the difference between ES and LS is greater in relation to "General economics". Nevertheless this difference remains non-significant.

4.2.4 Node relation dimension

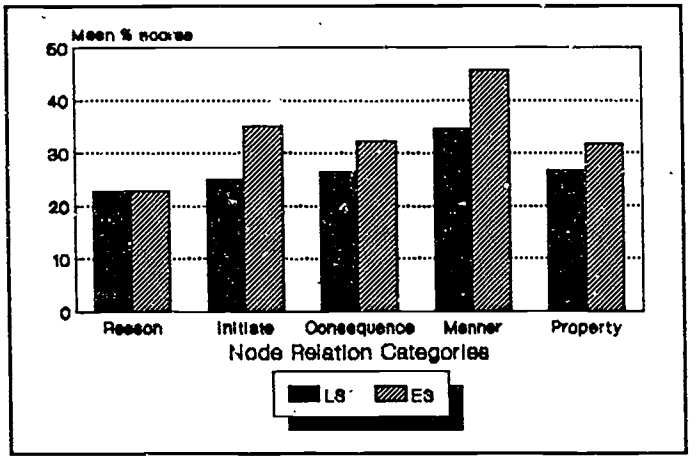

Figure 6 : Node relation knowledge profile

There seems to be hardly a difference in the mastery of the "Reason" node relation category. But as commented in the former part of this text, this parameter is of little relevance due to the restricted number of items on which the scoring is based. The biggest difference between the mean %-scores of ES and LS is observed in association with the "Initiate" and "Manner" node relation category. Only the latter difference is statistically significant, but at the 5%-level ($F=3.755$, $p_F=.05$).

4.2.5 Behavioural level dimension

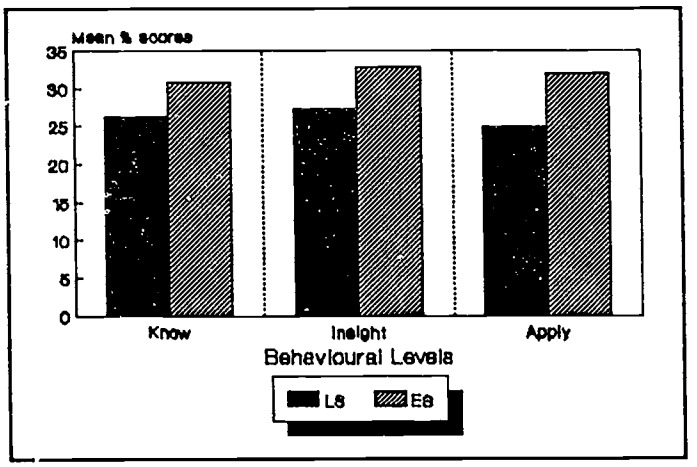

Figure 7 : Behavioural knowledge profile

At the theoretical level, it is expected that differences, found at a lower behavioural level, have an impact on differences in relation to higher behavioural levels. Figure 7 gives support to this hypothesis since initial differences on the "Know"-level widen to bigger differences at the "Apply"-level. But the differences between ES and LS remain non-significant.

4.2.6 Content level dimension

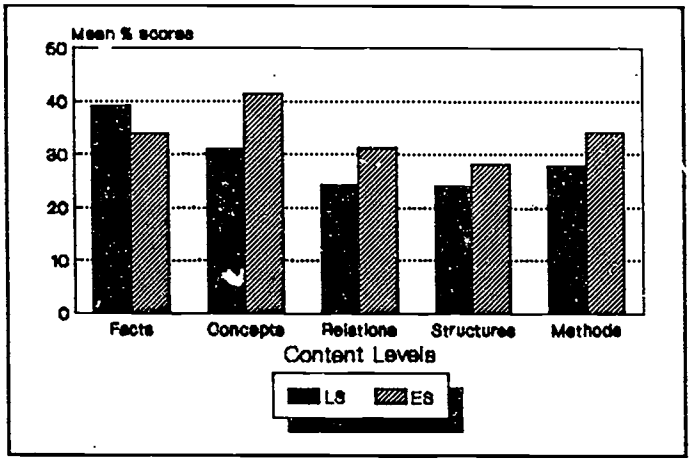

Figure 8 : Content knowledge profile

The "Content level" knowledge profile is also based on a hierarchical categorisation of domain knowledge. Figure 8 presents a peculiar prior knowledge state profile of ES and LS. "Factual" knowledge seems to be higher for LS. But from this level on, the mastery of ES is always superior. This can be explained : ES have already integrated the factual knowledge in more complex structures or schemes (e.g. concepts, relations, structures). Therefore, the immediate availability of the isolated knowledge elements is less elaborated than for law students. But the integrated factual knowledge is more readily available and more functional. In the knowledge profile, the differences between ES and LS are the biggest at the "Concept"level. This difference is only slightly significant ($F=4.729$, $p_F=.03$).

4.2.7 Epistemological level dimension

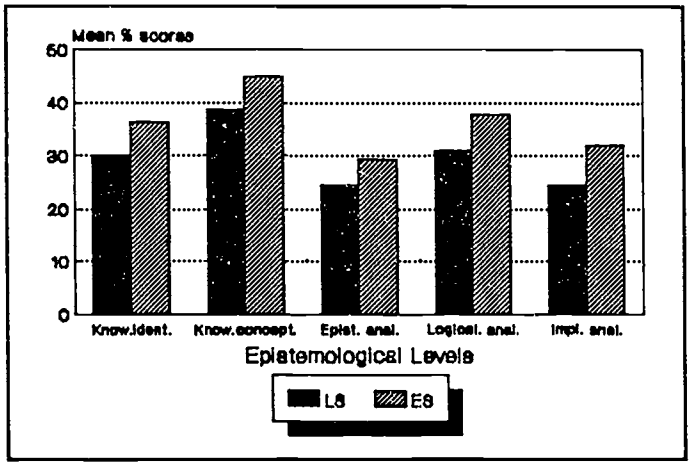

Figure 9 : Epistemological knowledge profile

Although the knowledge profile of ES is consistently higher than the profile of LS, the differences in mean %-scores are non-significant.

4.2.8 Representation level dimension

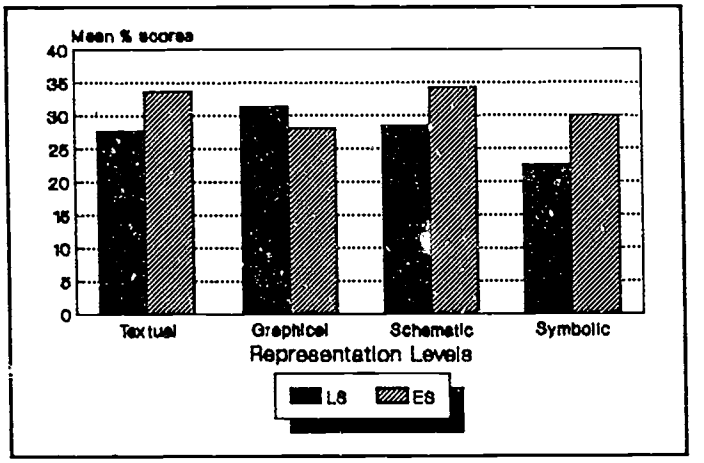

Figure 10 : Representation level knowledge profile

The mastery of representation levels suggests that LS are more able to solve questions based on graphical information. ES seem to master questions, based on symbolic information to a higher extent. Although interesting, none of these differences in mean %-scores are statistically significant.

4.2.9 Amount of propositions dimension

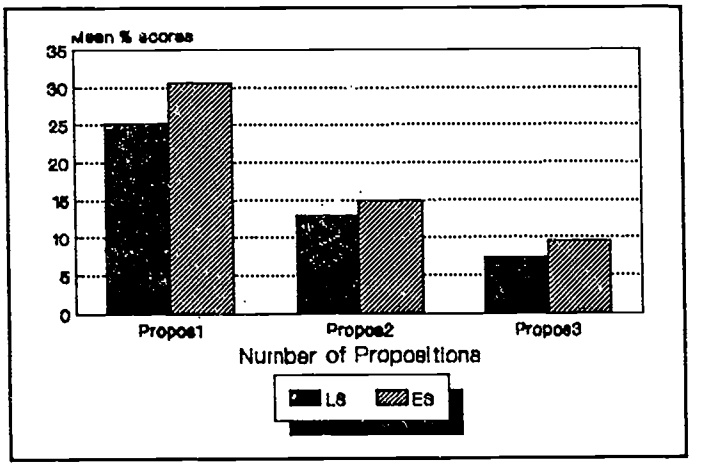

Figure 11 : Number of propositions knowledge profile

Items with a high number of propositions are more complex than items with a low number of propositions. It is expected that ES perform better at all proposition-levels. The profiles in figure 11 give support to this hypothesis, but statistical analysis does not reveal significant differences in mean % scores of ES and LS.

4.2.10 Information level dimension

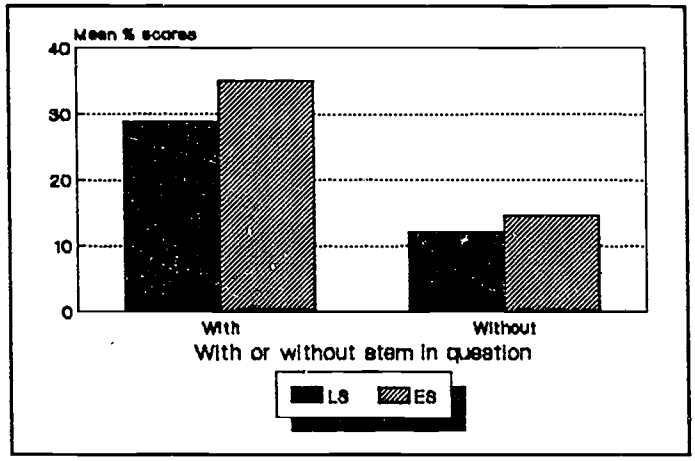

Figure 12 : Information level profile

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 ES perform better in relation to both types of questions, these differences in mean %-scores are not statistically significant.

4.2.11 Intermediate conclusions

Table 3 on the next page gives an overview of the results of the univariate analysis of variance when comparing the mean % scores of ES and LS[6]. Although the different dimensions help to differentiate between ES and LS, the different 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" might not be a relevant "indicator" of the prior knowledge state (Dochy and Valcke, 1991, Valcke and Dochy, 1991). The initial non-significant difference between both sub-populations (overall economy-score) is confirmed, but again the general trend that ES perform better than LS can be repeated.

4.3 Profile analysis

An univariate analysis of variance (as used in part 4.2 of this text) does not take into account the intercorrelations between the different parameters along the profile dimensions. These intercorrrelations are important (although not making the specific variables redundant) and can be explained at the theoretical level as clarified elsewhere (cf. Dochy and Valcke, 1991a). 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 ES and LS. A multivariate analysis can take these intercorrelations into account. Profile analysis is an extension of multi-variate analysis and is especially appropriate and helpful to evaluate the parameter structure in relation to each profile dimension when comparing subpopulations. 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. At the theoretical level, 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. A profile analysis will be performed on the complex of parameters in relation to each dimension.

[6] Since variances in both subpopulations are homogeneous, univariate analysis of variance can be applied.

The grouping variable is "diploma type" (ES or LS). SPSS-PC+ MANOVA was used for our profile analysis.

Table 3 :
Comparison of mean % scores of ES and LS

Dimension/parameter	m_{LS}	m_{ES}	F_{comp}	p_F
77 ES Report	34.6	39.8	1.277	.262
ES Finance	27.8	35.4	2.632	.109
ES Organ	37.4	47.2	3.484	.066
ES Market	34.8	45.9	4.554	.036
ES Macro	22.0	21.1	.037	.847
ES Micro	19.8	28.6	2.500	.118
ES Public	26.0	26.7	.019	.892
ES Internat	13.6	20.2	1.675	.200
ES Behav	20.0	19.4	.011	.916
CD Level1	26.2	32.2	2.546	.115
CD Level2	27.5	32.7	1.334	.252
CA Quant	25.7	27.5	.185	.670
CA General	26.7	32.9	2.319	.132
NR Reason	22.7	22.7	.000	1.00
NR Initiate	25.0	35.0	3.647	.060
NR Consequence	26.3	32.1	2.109	.151
NR Manner	34.5	45.8	3.755	.056
NR Property	26.7	31.7	1.506	.224
B Know	26.3	30.8	1.001	.320
B Insight	27.5	32.9	1.958	.166
B Apply	24.9	32.0	2.863	.095
C Factual	39.4	33.9	.921	.340
C Concept	31.1	41.4	4.279	.033
C Relation	24.3	31.4	3.100	.082
C Structure	24.1	28.1	.916	.341
C Skills	27.9	34.2	2.187	.143
E Kident	30.0	36.5	1.778	.186
E Kconcept	38.6	45.0	1.505	.224
E Epiate	24.6	29.3	1.367	.246
E Logical	30.9	37.8	1.962	.165
E Implem	24.7	32.0	2.977	.089
NP Propos1	25.2	30.6	1.890	.173
NP Propos2	12.9	15.0	1.296	.259
NP Propos3	7.4	9.7	3.062	.084
IL With stem	28.9	35.2	2.081	.153
IL Without stem	36.8	44.7	1.849	.178
RL Text	27.7	33.7	2.193	.143
RL Concrete	31.3	28.0	.315	.577
RL Scheme	28.6	34.3	1.524	.221
RL Symbolic	22.4	30.0	2.888	.093
General economics score	41.0	49.9	2.134	.149

4.3.1 Control of underlying assumptions

Profile analysis implies that specific assumptions about the quality of the research data are met (no missing data, comparable sample sizes, (multivariate) normal distributions, no outliers, homogeneity of variance-covariance, multicollinearity).

- Data screening revealed no missing data.
- Although sample sizes are different for both subpopulations ($N_{ES}=55$; $N_{LS}=22$) no special difficulties are expected since only one independent variable is used.
- The evaluation of the homogeneity of variance-covariance matrices is based on the Cochrans C and the Bartlett-Box F test.
- To evaluate assumptions about multivariate normality, boxplots of the mean submeasures for each dimension have been screened.
- Multicollinearity is tested with the Bartlett test of sphericity.

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". Figure 13 presents e.g. a box-plot of the scores of ES and LS for the subtopic "marketing" on the "Economics subdomain" dimension. The wide dispersion of the scores is obvious. 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 E (Extremes) if more than 1.5 interquartile distances away from the box.

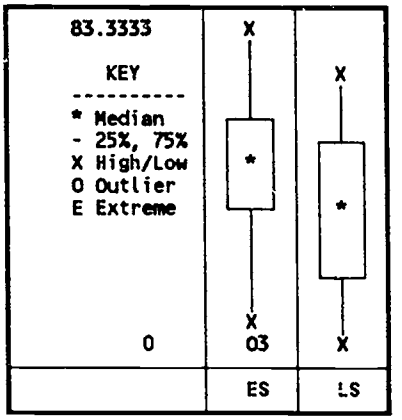

Figure 13 : Box-Plots

Analysis of the box-plots for each variable in relation to each profile dimension reveals that there are outliers and extremes, but that their number remains restricted.

Table 4 on the next page summarizes the data in relation to the evaluation of the homogeneity of variance-covariance matrices and the multicollinearity test.
Only in relation to one dimension, the assumption in relation to the **homogeneity of the variance-covariance** is violated ("curriculum accent" profile dimension).

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[7]. The fact, the MANOVA-procedure was never halted during execution indicates that multicollinearity did not cause problems.

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 "curriculum accent" dimension we will have to take care.

[7] 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
	Cochrans C	Bartlett-Box F	Bartlett test of sphericity
Report	.58927 (p=.270)	1.01650 (p=.313)	
Finance	.56895 (p=.396)	.59468 (p=.441)	
Organ	.56214 (p=.445)	.48021 (p=.488)	
Market	.57442 (p=.359)	.69644 (p=.404)	
Macro	.57772 (p=.338)	.76177 (p=.383)	414.729 (p=.000)
Micro	.50388 (p=.962)	.00179 (p=.966)	
Public	.50154 (p=.985)	.00028 (p=.987)	
Internat	.55784 (p=.477)	.38728 (p=.534)	
Behav	.61541 (p=.152)	1.74712 (p=.186)	
Level1	.67440 (p=.027)	4.30904 (p=.038)	137.071 (p=.000)
Level2	.58456 (p=.297)	.90772 (p=.341)	
Quant	.73804 (p=.002)	8.95013 (p=.003)	44.387 (p=.000)
General	.62313 (p=.126)	2.00645 (p=.157)	
Reason	.52082 (p=.799)	.05220 (p=.819)	
Initiate	.51153 (p=.888)	.01571 (p=.900)	
Conseq	.64177 (p=.076)	2.72172 (p=.099)	231.184 (p=.000)
Manner	.52962 (p=.717)	.10629 (p=.744)	
Property	.63044 (p=.104)	2.27185 (p=.132)	
Know	.50976 (p=.905)	.01139 (p=.915)	
Insight	.64714 (p=.065)	2.95243 (p=.086)	194.215 (p=.000)
Apply	.68483 (p=.019)	4.91687 (p=.027)	
Factual	.62458 (p=.195)	1.41734 (p=.234)	
Concept	.53584 (p=.660)	.15639 (p=.693)	
Relat	.61269 (p=.162)	1.66054 (p=.198)	310.881 (p=.000)
Struct	.61608 (p=.149)	1.76883 (p=.184)	
Methods	.69787 (p=.011)	5.75403 (p=.017)	
Kident	.53429 (p=.674)	.14295 (p=.705)	
Kconcept	.51209 (p=.882)	.01751 (p=.895)	
Episte	.62976 (p=.106)	2.24607 (p=.134)	282.645 (p=.000)
Logical	.64200 (p=.076)	2.73168 (p=.099)	
Implem	.66849 (p=.033)	3.98710 (p=.046)	
Propos1	.61666 (p=.147)	1.78776 (p=.181)	
Propos2	.67313 (p=.029)	4.23830 (p=.040)	189.357 (p=.000)
Propos3	.57821 (p=.335)	.77188 (p=.380)	
Withs	.67251 (p=.029)	4.20428 (p=.040)	105.279 (p=.000)
Without	.57486 (p=.356)	.70498 (p=.401)	
Text	.61061 (p=.170)	1.59631 (p=.207)	
Concrete	.52494 (p=.760)	.07512 (p=.784)	156.806 (p=.000)
Scheme	.63174 (p=.100)	2.32074 (p=.128)	
Symbol	.63486 (p=.100)	2.32535 (p=.127)	

4.3.2 Profile analysis results : parallelism test

Table 5 presents an overview of the analysis results in relation to the parallelism test. This helps us 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[8]. In relation to each profile dimension, Wilk's Lambda (λ) was calculated and p-levels determined. In the results table, Wilk's λ is not reported in relation to three dimensions (marked with *). This is because these dimensions only contain two variables; in these cases a test of significance for Hoteling's T^2 using the unique sums of squares was calculated, checking the interaction of the independent variable (diploma type) and the two dependent variables on the specific dimensions. For these cases the F-value and p_F-value are reported.

Table 5 :
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
Behavioural	.98878	.659
Content	.85856	.025
Epistemological	.97850	.811
Number of propositions	.97880	.453
Information level*	1.67*	.201
Representation levl	.93829	.197

If the multivariate analysis of variance indicates significant differences, the latter analysis can be extended by calculating structure coefficients[9] to determine the discriminatory power of the separate values on each profile dimension. This extra information will be embedded in the discussion of the table content.

The data in table 5 are not helpful to detect more 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 analysis of the overall economics-score, 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 univariate analysis of variance and the mean scores of both subpopulations in fig. 8, it is perceivable that the potential differences in the content profiles are especially caused by the differences in the mean % scores for test-items measuring the mastery of "concepts". But a significance level of $p = .025$ is - in our opinion - insufficient to continue our analysis.
Since the results indicate no significant differences at this level, a more elaborated profile analysis or the calculation of structure coefficients is not relevant.
As a consequence, the hypotheses stated in part 3.1 cannot be confirmed.

4.3.3 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 now especially relevant since the profiles are parallel, as has been found above.
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 of relevance in relation to the validity of the knowledge profile

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

[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.

dimensions.
The results of the flatness test are found in table 6. For each dimension Wilks λ has been calculated, with the exception of the three dimensions where only two parameters are available along the dimension; there the F-value is reported (marked with *).

Table 6:
Results of the flatness test in profile analysis

DIMENSION	*Wilks λ or F*	*p_λ or p_F*
Economics subdomains	.38041	.000
Curriculum*	241.16*	.000
Curriculum accent*	3.74*	.257
Node relation	.75791	.000
Behavioural	.95026	.151
Content	.61143	.000
Epistemological	.58562	.000
Number of propositions	.28480	.000
Information level*	178.23*	.000
Representation level	.87017	.017

With the exception of the "curriculum accent" and "behavioural level" dimension, all dimensions/parameters help to differentiate in the mastery of components of the prior knowledge state. The non-significant results for the "curriculum accent" dimension can be explained by the restricted number of items, measuring the mastery of general economics and B.A. The differences in the mastery of the prior knowledge state along the "behavioural level" dimension is indeed very small and as expected non-significant (cf. table 2).

5 Conclusions

In this text, we attempted to analyze the prior knowledge state of two specific Open university subpopulations, studying an economics course. Earlier research helped to confirm that prior knowledge state differences do exist between economics and law students. In the present study, the overall economics score was not significantly different between both student 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. The theoretical base of such dimensions was briefly outlined. In analyzing the research data, profile analysis was used as a specific extension of multivariate analysis of variance (parallelism test). The results of the analysis indicate that the grouping variable "diploma type" is not able to differentiate between levels of mastery of the prior knowledge state. Although this profile analysis - focusing on the parallelism test - could not help to reveal specific significant differences between the two subpopulations, the present study is of high importance since we succeeded in defining and operationalising a new more 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 dimensions might be 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.
The relevance of the knowledge profile dimensions was confirmed by the results of the flatness test during the profile analysis. Most dimensions help to differentiate in the mastery of specific components of the prior knowledge state.

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