A.M. MINNAERT, P.J. JANSSEN

# The causal role of domain-specific prior knowledge on study skills and curriculum outcomes after five academic years

Lic. A. Minnaert is assistent at the Department of Psychology, Centre for Schoolpsychology, Catholic University of Leuven, Belgium.
Prof. Dr. P.J. Janssen is full professor at the Department of Psychology, Centre for Schoolpsychology, Catholic University of Leuven, Belgium.

*Entrance selection of freshmen is not customary in Belgium. Due to this fact, failure rates of freshmen are relatively high (De Neve, 1991): 60 per cent in Human Sciences, 51 per cent in Biomedical Sciences en 49 per cent in Exact Sciences. In higher education outside universities the outcomes are as 'dramatic'. Apparently these freshmen didn't appropriately assess their potentialities in starting their career at the higher education level. In order to improve psychological and educational insights into this so called 'threshold' of the first year in higher education, a structural model of studying to explain individual differences in academic achievement is designed. It was applied in a specific department of a Belgian university.*

## Empirical and theoretical background

To imitate the study situation of a first year student, we designed a test which was presented as 'an excursion into the domain of my future study'. The underlying theoretical framework was derived from Janssen's (1989) theory of studying as *the integration of learning and thinking on the base of motivation*. We assume that academic performance in higher education is influenced directly and/or indirectly by a combination of cognitive and motivational variables.

To enhance insight into the process of studying, a content valid study-skill test was designed as an imitation of the situation of a first year student (Minnaert & Janssen, 1992). A brief description of that study situation follows as far as this is relevant to the objectives of this contribution. Within a limited amount of time this student has to study an explicit amount of new information within the chosen domain of study. Depen-dent on the curriculum completed in secondary education, on the domain-specific prior knowledge and on his/her intrinsic motivation of the student, the acquisition of new information is more or less successfully (accurately and with speed) related to the cognitive structure already built up. This latter implies a process of goal-oriented restructuring of the knowledge into a new, even more complex structure (Janssen, 1989). In each stage his/her learning process has to be integrated with two distinct thinking processes: serialist thinking as a deep, stepwise analysis of the one problem after the other [hereafter called 'analyse'] and holist thinking in search for a broad synthesis of different elements from distinguished themes [hereafter 'synthesise']. Thinking and learning should be integrated on the basis of motivation in order to develop real expertise in subject matter. To evaluate the degree of obtained expertise, an oral and/or written examination of the different courses in the study programme (being followed) will take place at the end of the academic year. By imitating this situation in miniature at the beginning of an academic year, we intend to examine the relative importance of study skills (analysis, synthesis, goal-oriented restructuring...), domain-specific knowledge, domain-related interest and the curriculum completed in secondary education as determinants of success and progress in higher education. In the case we succeed, the student can realistically evaluate his/her future result in due time.

In the literature of higher education we find a lot of evidence about the impact of domain-specific prior knowledge on problem solving and study behaviour (Chi, Feltovich & Glaser, 1981; Dochy, 1992; Glaser, 1984; Vosniadou & Brewer, 1987), even demonstrated in different study contexts (open university, regular courses) and fields of study (for example: physics, astronomy, economy). With domain-specific prior knowledge we refer to structures of knowledge in terms of concepts, rules and algoritmes within a specified field of knowledge. The acquisition of domain-related knowledge involves not only knowledge related to domain-specific names, concepts, symbols, data, formula's and their interrelations, but also to formal schemata in a specific domain (cf. physical laws, grammer) and about a specific curriculum (facilties to move up and to change, dissertation, work field). These knowledge structure's should be developed in time and retrieved during each process of problem solving.

## Method

In the first week of the academic year 1986-1987, 169 freshmen in the Department of Psychology at the University of Leuven participated in our three hours study skill test. In september 1991, 40% of them graduated in time, 39% dropped out before and 21% showed at that moment a retardation of 1 to 3 academic years. The structural model was tested on a sample of 161 students (44 men and 117 women) who participated in all the final exams at the end of their first year at the university.

Our excursion involves three distinct tests. A hierarchical *silent reading test* – 10 content valid texts on topics in the study program of Psychology and appropriate multiple choise questions – was designed to measure the thinking processes in deep-level learning: serialist (analyse) and holist thinking (synthesise). To realise a maximum of content validity in our excursion, text fragments of different courses in the first two years of the study program were selected and adapted for this test. The variety in study program contents (psychology, philosophy, statistics, physiology, etc.) is equally represented by the different topics in our silent reading test. The students were also asked to evaluate their domain-related interest for each text separately.
Thereafter an *information test* was presented to measure domain-specific prior knowledge in psychology incidentally picked up during a well passed off process of vocational choice. Information about Psychology recently spread via newspapers,

Table 1. - *ML-solution of measurement model I (the values in italics are statistically significant: p<.05)*

| | LAMBDA KSI1 | LAMBDA KSI2 | LAMBDA KSI3 | $\theta_\delta$ | Φ | Φ KSI1 | Φ KSI2 |
|---|---|---|---|---|---|---|---|
| Domain-specific prior knowledge | | | | | | | |
| general | *.544* | 0* | 0* | *.704* | KSI2 | .030 | |
| difficult notions | *.326* | 0* | 0* | *.893* | KSI3 | *.381* | *.332* |
| course, curriculum | *.407* | 0* | 0* | *.834* | | | |
| Domain-related interest in | | | | | | | |
| social psychology | 0* | *.586* | 0* | *.657* | | | |
| differential psychology | 0* | *.606* | 0* | *.633* | | | |
| Curriculum completed in | | | | | | | |
| High School | 0* | 0* | 1* | .000 | | | |
| *Indices of Goodness-of-fit* | chi²=2.87 | | | df=7 | | | p=.897 |
| | GFI=.994 | | | AGFI=.982 | | | RMR=.030 |

*: Fixed values

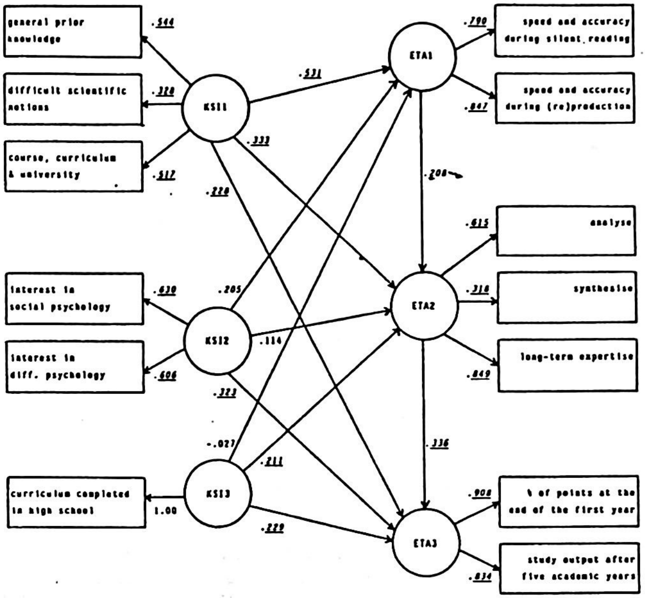
Table 2. - *ML-solution of measurement model II (the values in italics are statistically significant: p<.05)*

| | LAMBDA KSI1 | LAMBDA KSI2 | LAMBDA KSI3 | $\theta_\delta$ | Φ | Φ KSI1 | Φ KSI2 |
|---|---|---|---|---|---|---|---|
| Speed and accuracy | | | | | | | |
| during silent reading | *.803* | 0* | 0* | *.356* | KSI2 | *.454* | |
| during (re)production | *.847* | 0* | 0* | *.282* | KSI3 | *.373* | *.613* |
| Goal-oriented studying processes | | | | | | | |
| analyse | 0* | *.622* | 0* | *.613* | | | |
| synthesise | 0* | *.313* | 0* | *.902* | | | |
| long-term expertise | 0* | *.849* | 0* | *.279* | | | |
| Study success and progress | | | | | | | |
| after the first year | 0* | 0* | *.908* | *.176* | | | |
| after five years | 0* | 0* | *.930* | *.136* | | | |
| *Indices of Goodness-of-fit* | chi²=10.98 | | | df=11 | | | p=.445 |
| | GFI=.981 | | | AGFI=.951 | | | RMR=.033 |

*: Fixed values

curriculum information as is placed to students' disposal and domain-related information as is present in the suggested books as preparation before the start of the academic year, were the sources to formulate these domain-specific prior knowledge questions. The fact that almost no course of psychology is given in Belgian secondary education (only a very few exceptions exist), implies that there are no prerequisites concerning amount and content of prior knowledge in the field of psychology.
Afterwards all students took an *unannounced closed book 'exam'* about the content of the silent reading texts studied before. This 'exam' intended to measure the domain-related expertise as developed while studying intentionally the texts. This latter implies a process of goal-oriented restructuring of the acquired new information into the cognitive structure already built up.

We constructured fairly reliable (internal consistency varies from .67 to .86) measures




*Indices of goodness-of-fit*

| | | |
|---|---|---|
| squared multiple correlation ETA1 =.314 | chi²=51.60 | GFI=.954 |
| squared multiple correlation ETA2 =.384 | df=54 | AGFI=.922 |
| squared multiple correlation ETA3 =.550 | p=.568 | RMR=.048 |
| total coefficient of determination =.618 | | |

*Figure 1.* ML-solution for the structural model after five academic years (N=161) (the underlined values: p<.05; the values in italics: p<.10)

within each test (Minnaert & Janssen, 1992). The quantification of the variable *curriculum completed in High School* is borrowed from a follow-up of 6000 Belgian school-leavers (Stinissen, 1987). We used the standardized loadings of each curriculum in secondary education on the function that discriminate between successful and non successful students in Human Sciences. We inserted two measurements of academic performance into the model. The *percentage of points obtained at the end of the first exam period in the first year* is considered as an indication of academic success in the first year of higher education. The study progress in Psychology is specified by the *study output after five academic years*. This variable takes into account the degrees obtained (great distinction; distinction; successful but no distinction; not successful), the time needed to get that degree (first or second exam period; after an extra year) and the position reached in Psychology after five academic years (fifth, fourth, or third course year in Psychology; drop out after the first, second, third or fourth academic year). To evaluate the measurement models and the structural equation model by the parameter estimation method of Maximum-Likelihood (ML), the computer program LISREL was used (Jöreskog & Sörbom, 1989).

## Results and discussion

### *Statistical analysis of the measurement models*

We test the hypothesis of a simple structure matrix with unconstrained intercorrelations between the latent factors 'domain-specific prior knowledge', 'domain-related interest' and 'curriculum completed in High School'. The variable curriculum completed, on the whole considered as a cluster of intelligence, school knowledge, personality and study habits, is assumed to measure that cluster perfectly (KSI3). The first model fits the data well (table 1), indicating that the model cannot be rejected. Remarkable is the absence of any substantial correlation between domain-specific prior knowledge and domain-related interest, stressing the importance of both concepts.

Measurement model II (table 2) represents the hypothesis of a simple structure matrix with unconstrained intercorrelations between the latent factors 'speed and accuracy of study behaviour', 'goal-oriented restucturing study skills' and 'academic success and

**Table 3.** - *Logistic regression analysis for the (lack of) study progress*

| Domain-specific knowlegde | N | sig. of -2LL | GFI | sig. model-chi² | sig. variable(s) | R | sig. | predicted versus observed (lack of) study progress*: obs | predicted 0 | predicted 1 | | overall % correct classified | observed study progress |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LOW | 53 | .399 | .552 | .000 | KSI3 | .29 | .003 | | | | | | |
| | | | | | KSI2 | .12 | .081 | | | | | | |
| | | | | | | | | 0 | 19 | 7 | 73% | 75 | 50.9% |
| | | | | | | | | 1 | 6 | 21 | 78% | | |
| MEDIUM | 55 | .166 | .454 | .019 | ETA1 | .23 | .010 | | | | | | |
| | | | | | | | | 0 | 8 | 11 | 42% | 71 | 65.5% |
| | | | | | | | | 1 | 5 | 31 | 86% | | |
| HIGH | 53 | .954 | .869 | .000 | KSI3 | .27 | .011 | | | | | | |
| | | | | | ETA2 | .25 | .016 | | | | | | |
| | | | | | | | | 0 | 9 | 4 | 69% | 87 | 75.5% |
| | | | | | | | | 1 | 3 | 37 | 92% | | |

*: lack of study progress = 0; study progress = 1.

progress'. The ML-solution of measurement model II indicates that the model cannot be rejected on the ground of our data. The goodness-of-fit indices as well as the non-sigificant (p=.445) difference between the postulated model and the data confirm our initial measurement model.

*Statistical analysis of the structural equation model*

The hypothetical model consists of three latent exogenous KSI-variables (domain-specific prior knowledge, domain-related interest and curriculum completed in High School) which are not explained by the model. The ETA-variables are latent endogenous (Jöreskog & Sörbom, 1989). The two measurement models are now combined into one model with structural relations between the latent factors. According to our theory about studying, the factors speed and accuracy in study behaviour (ETA1) and goal-oriented restructuring (ETA2) are assumed to be influenced by the latent exogenous variables. The factor goal-oriented restructuring (ETA2) is influenced directly by the speed factor (ETA1). We consider success and progress in higher education (ETA3) to be determined by all the motivational and cognitive exogenous variables. We further hypothesized that goal-oriented restructuring (ETA2) has a direct effect on academic performance (ETA3).
The hypothesised LISREL model fits well the observed data and cannot be rejected ($Chi^2$ = 51.60, df = 54, p = .568): GFI = .954, AGFI = .922, RMSR = .048; it explains (R = .74) 55 per cent of the variance in study success and study progress after five years (figure 1). The structural equation parameters confirm the hypothesized effects of domain-specific prior knowledge (p<.05) , domain-related interest (p<.01), curriculum completed in High School (p<.01) and goal-oriented restructuring study skills (p<.01) on study success and progress in Psychology.
Furthermore, the results confirm the significant direct effect of domain-specific prior knowledge on the speed and accuracy of study behaviour (p<.01) and on goal-oriented restructuring (p<.05). So the hypothesis that the amount of present knowledge (schemata for understanding) is an important determinant of goal-oriented restructuring in studying new information cannot be rejected. This finding is equal to the expert-novice paradigm that experts in an area learn more when studying new information in their domain of expertise than novices do in that domain (Voss, Fincher-Kiefer, Greene & Post, 1986). Glaser (1984) already pointed out that the amount of initial problem solving representations influences the efficiency and accuracy of thinking and learning within that specific domain.

The importance of both declarative and procedural knowledge is already stressed by other researchers (Decruyenaere & Janssen, 1989; Weinert, 1987). Although the direct effect of domain-specific prior knowledge on goal-oriented restructuring isn't very substantial, the total effect (the sum of direct and indirect effects) is significant at the 1% level. The same conclusion can be drawn about the effect of domain-specific prior knowledge on the study success and progress after five years. Domain-specific prior knowledge as well as domain-related study skills are necessary prerequisites to accomplish study success and progress in Psychology. Besides, differences in curriculum outcomes are also significantly (p<.01) influenced by differences in domain-related interest.

In order to verify the substantial role of domain-specific prior knowledge and domain-related skills in studying, we examined the probability of study progress during five academic years. Therefore we used logistic regression analysis (Hosmer & Lemeshow, 1989) in a group of low, medium and high levels of domain-specific prior knowledge. In each logistic regression model the (lack of) study progress functions as categorical dependent variable and the structural equation variables in the LISREL-model (of course without ETA3) are the independent measures.
The statistic '-2 times the log of the likelihood' (-2LL) is a measure of how well the estimated model fits the data. A good model is one that results in a high likelihood of observed results and consequently in a significant $chi^2$. The goodness of fit of these models are quite satisfying (varying from .454 to .869) and the model $chi^2$ – testing the null hypotheses that the coefficients for all the terms in the current model, except the constant, are 'zero' – are all significant. This indicates that the variables in the equations are substantial. The contribution of each variable in a logistic regression is difficult to determine because of the intercorrelations between the independent variables. The R statistic is used to look at the partial correlation between the dependent variable and each of the independent variables. Only those variables that have a substantial contribution to the logistic regression model are represented in table 3.

Within the group of low level domain-specific prior knowledge (75% correctly classified) differences in curriculum completed in High School (KSI3) turn out to be very substantial in the prediction of study progress, while differences in domain-related interest (KSI2) contribute less substantially as curriculum completed. Within the group of medium level prior knowlegde (71% correctly classified) differences in the speed and accuracy of information processing in study behaviour (ETA1) are significant. Within the group of high level prior knowledge (87% correctly classified) differences in curriculum completed in High School (KSI3) and in goal-oriented restructuring study skills (ETA2) significantly predict study progress. The logistic regression models stress the importance and the compensatory effects of other cognitive and motivational factors in the prediction of study progress more than the level of domain-specific prior knowlegde alone. Noteworthy is the fact that students with a high level of domain-specific prior knowledge have an observed success ratio of three on four, while students with a low level have only a success ratio of one on two. Is it still so obvious that rich domain-specific knowledge strongly influences study performances in the domain of interest even after several years? Although many researchers already demonstrated the importance of domain-specific prior knowledge on problem solving, even at the level of higher education (cf. Chi, Feltovich & Glaser, 1981; Decruyenaere & Janssen, 1989; Dochy, 1992; Vosniadou & Brewer, 1987), none of them reports research on the direct and/or indirect effects of domain-specific prior knowlegde on the quality of graduating (in time, with retardation, not at all, with or without a degree) in the domain of interest.

## Conclusion

Failure rates of freshmen in Belgian higher education are relatively high. Apparently these freshmen didn't appropriately assess their potentialities in choosing their curriculum at a university level. In order to promote more realistic choices we developed a content valid, theory based study excursion test for psychology at the KU Leuven. 169 Freshmen took voluntarily this 3 hours test at their start in October 1986. In 1991, 40% of them graduated in time, 39% dropped out before and 21% showed at that moment a retardation of 1 to 3 academic years. Constructs measured in the test were combined with students' program in High School into a LISREL model, explaining (R=.74) 55% of variance in study success and progress after five years, confirming so the hypothesized effects of domain-specific prior knowledge, the type of High School completed, domain-related interest and study skills on study success and progress in Psychology. Furthermore, the results confirm the significant direct effect of domain-specific prior knowledge on the speed and accuracy of study behaviour and on the study skills as measured in our test. The model confirms the hypothesis that domain-specific prior knowledge as well as study skills are both necessary prerequisites to accomplish study success and progress without retardation or drop out. By consequence, our instrument has the necessary validity to promote better choices of entering freshmen, when applied at the right stage during the process of vocational choice.

The results of this research on studying in higher education force us into further investigations on the acquisition of structures of domain-specific knowledge in relation to domain-related study skills. On the base of its content and nomological validity, our instrument has the necessary predictive validity (R=.74) to promote better vocational choices of entering freshmen. It would imply lower failure rates of freshmen – given constancy of criteria – in the case the faculty should have the right to select its first year students. As yet it has not.

## References

Chi, M.T., Feltovich, H. & Glaser, R. (1981) Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5*, 121-152.

Decruyenaere, M. & Janssen, P.J. (1989) A structural model for individual differences in academic performance of freshmen. In: H. Mandl, E. De Corte, N. Bennett & H.F. Friedrich (Eds.), *Learning and Instruction. European Research in an International Context: Volume 2.1* (481-495). Oxford: Pergamon Press.

De Neve, H. (1991) *Studierendementen aan de K.U.Leuven in de Periode 1984-85 tot en met 1988-1989* [Study outputs at the K.U.Leuven in the period 1984-85 upto 1988-89]. Leuven: Dienst Universitair Onderwijs.

Dochy, F.J.R.C. (1992) *Assessment of prior knowledge as a determinant for future learning.* Utrecht/London: Lemma b.v./Jessica Kingsley Publishers.

Glaser, R. (1984) Education and thinking. The role of knowledge. *American Psychologist, 93*, 93-104.

Hosmer, D.W. & Lemeshow, S. (1989) *Applied logistic regression.* New York: John Wiley and Sons.

Janssen, P.J. (1989) Task, development and process in student learning: toward an integrated theory of studying. *European Journal of Psychology of Education*, *4*, 469-488.

Jöreskog, K.G. & Sörbom, D. (1989) *LISREL 7 User's Reference Guide* (1st ed.). Mooresville, Indiana: Scientific Software, Inc.

Minnaert, A. & Janssen, P.J. (1992) Success and progress in higher education: a structural model of studying. *British Journal of Educational Psychology*, *62*, 184-192.

Stinissen, J. (red.) (1987) *De overgang van secundair naar hoger onderwijs. Een follow-up van 6000 abituriënten – Rapport 3: Doorstromen en slagen* [The transition of High School to Higher Education. A follow-up of 6000 school-leavers – Report 3: Move up and succeed]. Leuven: Acco.

Vosniadou, S. & Brewer, W.F. (1987) Theories of knowledge restructuring in development. *Review of Educational Research*, *57*, 51-67.

Voss, J.F., Fincher-Kiefer, R.H., Greene, T.R. & Post, T.A. (1986) Individual differences in performance: The contrastive approach to knowledge. In: R.J. Sternberg (Ed.), *Advances in the psychology of human intelligence* (Vol. 3, 297-334). Hillsdale, NJ: Erlbaum.

Weinert, F.E. (1987). Developmental processes and instruction. In:E. De Corte, H. Lodewijks, R. Parmentier & P. Span (Eds.), *Learning and Instruction. European Research in an international context: Volume 1* (1-18). Oxford/Leuven: Pergamon Press/Leuven University Press.