Effects of Problem-based Learning in Business Education : A Comparison between a PBL and a Conventional Educational Approach

Effects of Problem-Based Learning in Business Education: A Comparison Between a PBL and a Conventional Educational Approach

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1. INTRODUCTION

Over the past decade, business schools have been increasingly criticized for being too theoretical, too specialized, not internationally oriented and not engaged in developing the necessary expert knowledge in students (Gijselaers & Woltjer, 1998). In the workplace of the current "Age of Mind" (Todd, 1999), knowledge is a valuable asset of the contemporary organization. In order to be successful in the current dynamic and competitive environment, the use of existing knowledge and the development of new knowledge becomes a prominent prerequisite for solving the complex problems faced today. In view of these developments, the question that needs to be asked is: "What qualities must graduates of business education possess?" Many answers to this question have been formulated in the literature. These share a common view. Society demands graduates who are capable of efficiently resolving complex problems (Engel, 1997; Poikela & Poikela, 1997; Segers, 1997).

Concomitant with recent developments in society, insights have been formulated in cognitive psychology and instructional theories, such as constructivism, which have consequences for educational practice. Research on expertise has made clear that an enormous amount of knowledge needs to be mastered to serve as a basis for expert performance (Gijselaers & Woltjer,

1998). At the same time, research has made clear that expertise development is not simply a matter of adding new information to existing knowledge. For expert knowledge is organized in such a way that it is readily applicable in practical settings (Van de Wiel, 1997). Therefore in education the focus should be not only on acquiring knowledge, but also on students being trained in using knowledge efficiently (Arts, Gijselaers & Boshuizen, 2000).

What can business education learn from this research on expertise development (Gijselaers & Woltjer, 1998)? During knowledge acquisition, students should be stimulated to analyze business cases and relate business theory to these cases. Thereby, students should be stimulated to conduct their own information searches and ask their own questions. Small group work enables this process. If teaching for expertise is to be considered as shifting away from learning factual knowledge and principles to learning how to use this knowledge in complex problem-solving situations, curricula should consist of a considerable amount of problems that are not disciplinary pre-packaged.

2. PBL IN BUSINESS EDUCATION

As a result of these developments in society and educational science, a number of concrete innovations have been introduced in business education, which may be labelled as "student-centred education". Changes are mainly happening in the following three directions: from knowledge as a goal to knowledge as a tool; and from passive to active and independent learners; and from directive to coaching teachers. Students' activities and learning processes are always at the centre (Vermetten, 1999). An example of such a student-centered approach in higher education is problem-based learning (PBL). Although originally developed for medical training in Canada, the orthodox version of PBL is applied globally in many disciplines (Gijselaers, 1995), including business education. The desire to implement PBL as an alternative for existing teaching practices inevitably raises the question of whether PBL is an alternative capable of effectively replacing conventional curricula (Albanese & Mitchell, 1993) in educating business experts. Although contemporary educational practice increasingly consists of a blend of conventional and student-centered, it seems a good idea to compare the merits of the two approaches.

Van den Bossche, Gijbels and Dochy (2000) sought to answer this question by conducting a meta-analysis. The results of this survey suggest, in all instances, a strong and significant effect of PBL on the application of student knowledge. As to student knowledge, after a single course based on PBL virtually no difference was observed by comparison with students

learning by conventional methods. Learning by "conventional methods" must be taken to mean those forms of education, which are strongly teacher-centered, in which transfer of knowledge by the teacher is the predominant method. In most instances, teaching takes place in large groups. As to the effect of a fully problem-based curriculum on student knowledge, the outcome showed a slight tendency towards negative results.

However, only one of the 43 studies included in the statistical meta-analysis was situated in the domain of business education (Son & Van Sickle, 2000). This study found small positive effects on the knowledge acquisition of the implementation of PBL in two business courses.

Given the fact that PBL becomes more and more implemented in business-curricula (Gijselaers, 1995), further research should be undertaken into the possibility of generalization as a result of the effects found for domains other than medicine. In the study discussed below, the effects on business students' knowledge and knowledge application of a curriculum-wide implementation of PBL were investigated. The following core sub-questions needed to be answered.

- "To what degree do students studying in a problem-based curriculum possess an accessible knowledge base of the subject studied in comparison with students to whom the subject was presented in the conventional way?"
- "Are students who have been subjected to PBL better equipped to apply the knowledge of the subject studied than students to whom the subject was presented in the conventional way?"

2.1 Hypotheses

The research questions deal with knowledge acquisition and application of knowledge issues. For these categories, both developmental aspects and differences between educational formats are discussed.

2.1.1 Knowledge Acquisition

During the first two years of their higher education, students are exposed to a lot of new information. The acquisition of a scientific knowledge base of the respective domain is a main goal. In conventional education, the first two years of training are mainly devoted to the acquisition of knowledge. In a problem-based curriculum knowledge application is an important goal from the start. Here, knowledge is seen as a tool (Dochy et al., 2002). The results of the meta-analysis by Van den Bossche and colleagues (2000) indicated that in the starting years the knowledge base of students in a conventional

medical curriculum is not as large as the knowledge base of students following a problem-based curriculum.

However, it can be assumed that the characteristics of PBL as a powerful learning environment bring about a "better structured" knowledge base. This makes the acquired knowledge better available in the future (Gagné, 1993). Results from the meta-analysis seem to confirm this (Van den Bossche, Gijbels & Dochy, 2000). This is a possible explanation for the fact that PBL students in the later years of their training score at least as good as the students out of a conventional curriculum on a knowledge reproduction test.

The expectation is that business students following a problem-based curriculum will do slightly worse than their counterparts in a conventional curriculum on a knowledge reproduction test. However, the difference between these two groups will become smaller and possibly even culminate in a higher score for the PBL students at the end of their program.

2.1.2 Knowledge Application

It can be assumed that all students become more adept at the application of acquired knowledge through their training. In PBL authentic problems are the starting point for acquiring and applying knowledge. In the conventional curriculum one has no explicit requirement for the application of knowledge until after the second year. This means that the acquisition of basic knowledge precedes learning how to apply it.

In line with the above, research indicates that a curriculum-wide implementation of PBL in the medical domain has clear positive effects on the ability of students to apply the acquired knowledge (Van den Bossche, Gijbels & Dochy, 2000). This effect is noticeable in every year of the curriculum. The expectation is that business students pursuing a problem-based curriculum will be more capable of applying the acquired knowledge than students following a conventional curriculum and this should be true in every year of the curriculum.

3. METHODOLOGY

3.1 Research Population

The research population consisted of business students at two institutes. The first institute delivers an educational program that can be characterized as conventional. It is discipline-oriented with formal lectures as main part of the educational activities and is located in a Belgian university. A

characteristic of this program is that of free entrance for all students. The other institute has a problem-based curriculum. Students meet each other twice a week in small tutorial groups, of between 12 and 15, guided by a tutor. In these groups they are confronted with authentic problems, problems which they might encounter in real life situations. Because authentic problems are often not solvable within mono-disciplinary constraints, the curriculum is organized on a multidisciplinary basis. This implies that problems are discussed from different disciplinary points of view. The problems are the context in which the students study the basic concepts and models within the fields of economics (Segers, 1997). A Dutch Faculty of Economics organizes this problem-based education. At this institute there is a kind of "selection at the gate". Students are only admitted when they have completed certain preliminary training.

3.2 Sample and Procedure

The specific situation of both institutes compelled us to undertake an adapted sampling in both institutes.

3.2.1 The Conventional Institute

All the subjects of the population were part of the sample, except at the start of Year 1 where a random sample was taken. This resulted in 50 participants for the pretest, while 16, 15 and 22 students, respectively, participated in the tests at the end of Year 1, Year 2 and in Years 3 and 4.

3.2.2 The PBL Institute

All tests were taken from a random sample of the population, except at the start from Year 1 where a quota sample procedure was used. 13 students participated in the pre-test. There were, respectively, 21 and 46 students for the test at the end of Year 1 and Year 2. Also 54 students from Years 3 and 4 participated in the study.

3.3 Research Design

Because the research was conducted in a "real-life" context a random distribution of the subjects over experimental and conventional groups was not feasible. In using this quasi-experimental design internal validity is more vulnerable than in an experimental design and generalizability can be merely presumed. Its great advantage lies in its ecological validity that is the extent

to which findings can be generalized to the "real world" (Campbell & Stanley, 1963).

In this research the focus was on the subject of macroeconomics, as part of the economic curriculum. A curriculum-analysis was conducted in order to find out when and to what extent macroeconomics had a place in both curricula. Particularly in the first two years a difference was found between the two curricula.

In the disciplinary-oriented curriculum of the conventional institute a general economics course, in which the macroeconomic context is covered, is taught in the first year. In the second year of their studies, the students have to follow a course dedicated to macroeconomic theories and insights. In the third and fourth year students follow a range of courses in which the application of macroeconomic content is required.

As a consequence of the multi-disciplinary approach of the curriculum in the PBL institute, it is not always possible to ascertain the points at which macroeconomic concepts need to be applied. However, in the first year of the course, the macroeconomic way of seeing is already explicitly placed at the center. Also in the second year attention is given to the macroeconomic perspective.

This difference in the structure of the curriculum is important for a correct interpretation of the results. A pretest was taken in order to check the prior knowledge of the students. Next, tests were taken after one year. For PBL students (i.e. those selected at the gate) this was at the end of Year 1 and for those receiving conventional education (selection in Year 1) at the start of the second year. This difference in the point of assessment was introduced to adjust for the difference in prior knowledge that could be recorded as a consequence of the difference in the moment of selection. A third test was conducted at the end of Year 2. As a result of the structure of the programs, in Years 3 and 4 of both programs (a student can choose when s/he follows certain courses), the fourth test was taken from a mixed group of third and fourth year students.

3.4 Research Instrument

Both the acquired knowledge and the degree to which students are capable of applying the knowledge were evaluated. Therefore, two instruments were used: a knowledge-test and a case-based test.

3.4.1 The Knowledge Test

The knowledge test measures primarily factual knowledge, the meaning of symbols and the concepts and principles pertaining to a particular theme.

This type of knowledge is called declarative knowledge (Anderson, 1983; Dochy & Alexander, 1995). The items contained in the knowledge test require the students to reproduce their knowledge and/or demonstrate insight. It is not sufficient for students to remember or even understand isolated definitions of domain-related concepts. They need to understand the frame of reference that organizes them (Segers, 1997; Segers, Dochy & De Corte, 1999).

To assure relatively even coverage of the domain, an analytic grid is used for the construction of the test.

Item 1:
True/?/false The Gross domestic product measures the total spending of all residents of an economy.

(false)

Item 2:
A car manufacturer takes more employees in service and pays their wages. As a consequence the production increases, which is held in stock for selling later.

True/?/false The gross domestic product (GDP) increases.

(true)

Item 3:
Suppose there is inflation, and the Central Bank changes the growth rate of the money supply so as to equal the long term annual growth rate of production. Suppose also that people believe this money growth rate will continue to equal the growth rate of production. In the following several immediate effects are mentioned.

True/?/false An immediate effect would be that the nominal interest rate would fall. (true)

True/?/false An immediate effect would be that actual inflation would temporarily be negative. (true)

Figure 1: Examples of Items from the Knowledge Test.

These examples assess conceptual understanding. The first and the second questions require students to be able to recognize the definition of the gross domestic product. The second question is embedded in a simplified authentic situation. It asks for more than merely factual recall. Students have not only to reproduce the definition of the concept, but also apply it to the case of the car manufacturer. Since only the relevant variables are mentioned, students do not need to retrieve the relevant information from the case in order to be able to answer the question. The third question starts from a macroeconomics case which, like the second question, presents the critical elements for solving the problem. To answer the questions, students need to understand the various relevant concepts (nominal interest rate, inflation,

rate of growth of the money supply, long-run annual growth rate of production). Additionally, they are required to master the interconnections between these concepts.

As is clear from the examples, we used the "question mark" option. This option allows the students "to pass" on a particular question. Students who circle the question mark option indicate that they have not mastered the subject. This option allows them not to give an answer and therefore to avoid guessing. They are not punished for not knowing. Choosing the question mark option gives a score of 0 points. On the other hand, they lose one point (-1) when giving the wrong answer. Circling the right answer means +1 score. The introduction of this scoring system makes guessing only attractive for students who are reasonably sure of the answer. Therefore, in most cases choice of the wrong answer reveals that students have misunderstood the objective measured (Segers, 1997; Segers, Dochy & De Corte, 1999).

3.4.2 Case-based Test

In this test, students are confronted with a case that describes a macroeconomic problem. Essay-type questions are posed about this problem. The case-based test measures whether students are able to retrieve the relevant concept (model, principle) for the problem. Furthermore, it measures if they can use these instruments to solve the problem. It measures if the knowledge is usable (Glaser, 1990) or whether students know "when and where" (conditional knowledge). In short, the test measures the extent to which students are able to analyze problems and contribute to their solution by applying the relevant tools (knowledge). Figure 2 gives an example of such a question.

Case: THE NV BELGIUM (for a complete description of the case: contact the first author)
Question: Give two actions the Belgian government can take as part of a policy in the tradition of Keynes and describe the consequences of the actions by means of the IS/LM model.

Figure 2: An Example of a Case-based Question.

3.4.3 Difference Between the Knowledge and the Case-based Test

The knowledge test aspires to measures what the students know. The test appeals to their reproductive thinking. Besides, and this is the maximum, the test measures if they are capable of using the learned subject matter, but only in situations where solution and solution strategy is defined in advance. This is known as convergent thinking (Tempelaar, 1993).

The case-based test measures the ability to apply. In other words, can the student also apply the learned subject matter in situations where different ways to reach the solution are possible? This is known as divergent thinking (Tempelaar, 1993) or creative application (Block de & Heene, 1992). In addition, the case creates a more complex context than any knowledge test ever can.

The difference between knowledge and application is best seen as a continuum, with the knowledge test tending towards the knowledge pole and the case-based test towards the application pole.

3.5 Concrete Operationalisation and Construction of Instruments

3.5.1 Knowledge Test

Different parallel tests were used in this research. Teachers of both institutes screened these tests for content and instructional validity. Instructional validity refers to the similarity between the operational curriculum and what is being tested (McClung, 1979). None-relevant items were removed from the tests. The content validity is assured by the use of the analytic grid for the construction of the test. This was also double-checked by a teacher in the conventional institute.

Furthermore, the tests were comparable concerning difficulty. To assure this, the p-values of the tests as a whole were calculated. The p-value is defined as the proportion students that choose the correct alternative (Dousma & Horsten, 1995). To ascertain the p-value of the different test, data were used from the summative use of a different test in the curriculum of the PBL institute. The tests were all filled in by comparable groups of approximately 280 students. The p-values of the different tests were respectively 0.60, 0.52, 0.57 and 0.59. One can conclude that all these tests have the same degree of difficulty.

3.5.2 Case-based Test

An authentic case was formulated by experts in the field of macroeconomics. The construction and review of the problems were guided by a set of criteria for case writing (Leenders & Erskine, 1989; Van Vilsteren, Van der Heijden & Arts, 1993). The described economic problem starts with an introduction, presenting information about the context and the position of the student. The specific problem situation is described next. The problem description ends with two questions.

The schemes for the analysis of the responses were based on a detailed model for problem-analysis by the expert-constructors. A specialist in the content matter evaluated the responses of the students. One of the authors of this article acted as second reviewer. Central criteria for the coding were the number of correct concepts, relationships between the concepts used for problem analysis and the correctness of the product (i.e. solution of the problem).

4. RESULTS

In the first part of this section the results of the knowledge-test are presented. In the second part a description of the results for the case-based test is provided. To begin the pre-test is analyzed by independent t-tests to discern differences in the prior knowledge of the students. Then the expertise (-development) of the students in both learning environments is analyzed by a 2 x 3 analysis of variance. The interpretation of the main effects will be done by analyzing the marginal means and their respective 95% - confidence intervals. The interpretation of the interactions will be done by studying the pattern of means (and their confidence intervals) and the effect-sizes per expertise-level (d-index; Cooper, 1989).

4.1 Knowledge Acquisition

4.1.1 Pre-knowledge Test

Both groups score very low on the knowledge test at the moment of the pre-test. The students of the conventional institute have a mean total score of 2.88%. The mean total score of the students of the problem-based institute is 7.37%. This difference (4.48%) reaches a significant level ($t = 2.14$, $df = 61$, $p = .036$, CI: +/- 4.18%).

As a consequence of the specific context of the institutes (selection at the gate or after the first year of training) a difference in results could be expected. The selection in the conventional institute happens at the end of the first year. From that moment on, the two groups can be considered as equal. By accommodating the second moment of measurement to these conditions (cfr. supra), the groups can be compared from that moment on.

4.1.2 Knowledge Development Through the Curricula

4.1.2.1 Total-score

The results of the analysis with the total score as a dependent variable are presented in table 1.

Table 1: 2 X 3 Analysis of Variance of the True Minus False Score in Terms of Percentage (Total Score)

	SS	Df	MS	F	P
Learning env (L)	1204.62	1	1204.62	8.50	.004
Expertise (E)	2826.13	2	1413.06	9.97	.000
L X E	1028.05	2	514.03	3.63	.029
Within	22812.40	161	141.69		
Total	73584.55	167			

Both the main effects and the interaction effect turn out to be statistical significant. The results between the expertise-level and the results on the knowledge-test is the most significant, followed by the effect of the learning environment and then by the expertise-learning environment interaction. The interpretation of these effects is guided by the plot of the means in figure 3, with the means and the effect-sizes based on the differences per expertise-level.

The significant main effect of expertise-level ($F(2,161) = 9.97$, $p = .000$, $MSw = 141.69$) is caused by the decline of the score of the total group. At the end of the first year they score 23.64% (CI: +/- 3.97%), at the end of the second year this is merely 15.31% (CI: +/- 3.81%) and in the third and fourth year 12.19% (CI: +/- 3.13%).

There is a significant relation between the learning environment and the result on the knowledge test, also when this is controlled for the level of expertise ($F(1, 161) = 8.50$, $p = .004$). The students of the PBL institute score higher than students of the conventional institute. Their scores are, respectively, 20.20% (CI: +/- 2.32%) and 13.96 (CI: +/- 3.53%). This results in an effect size of 3.49.

The analysis shows that a complete description of the results on the knowledge test must not only comprise the main effects, but also the interaction between the learning environment and the expertise-level. Also this effect is significant ($F(2, 161)= 3.63$, $p = .029$). The mean difference between the two learning environments is strikingly larger at the end of the first year than at the end of the second year and in the third and the fourth years.

The students of the PBL institute in Year 1 scored 31.00% (CI: +/- 5.13%). This is almost twice as good as the students of the conventional

institute who scored 16.27% (CI: +/- 6.07%). This resulted in an effect size of 4.79. The two groups converged at the end of Year 2, when the difference is only 1.69% (ES = 0.49). The students of the PBL institute have a mean score of 16.15% (CI: +/- 16.15%) which is still higher than the students of the conventional institute with a score of 14.46% (CI: +/- 6.79). Also in the third and the fourth year the students of the PBL institute score higher (13.43%, CI: +/- 3.20%) than the students of the conventional institute (11.15%, BI: +/- 5.39%). The difference is 2.29% (ES = 0.84).

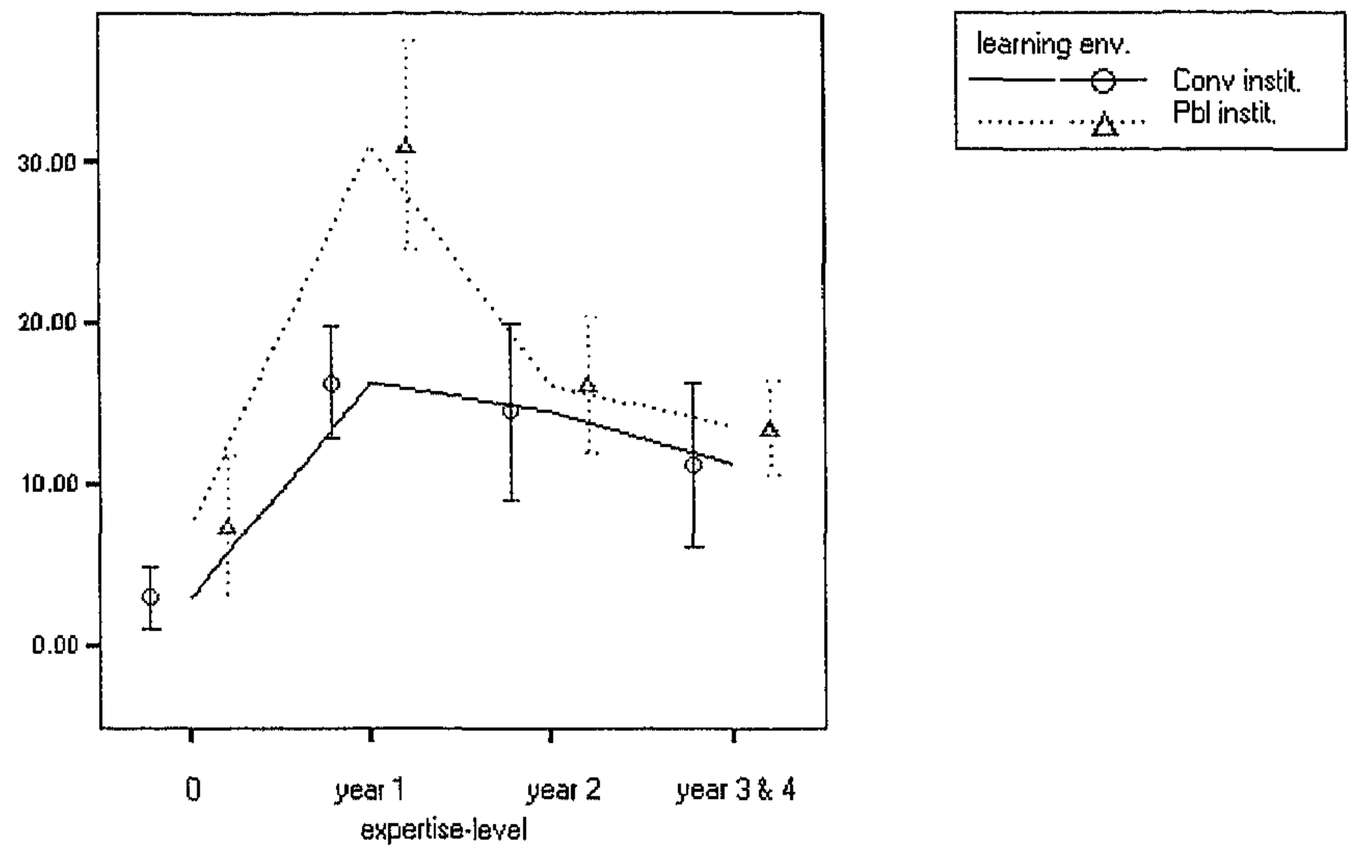

Figure 3: Mean Total Score (true minus false) as a Function of the Learning Environment and the Expertise-Level (the error bars show the 95% confidence intervals of the means).

The interaction effect is mainly due to the strong higher score of the PBL students at the end of Year 1. This difference disappears at the other expertise-levels. However, the tendency that the students in a PBL environment get higher scores than students in a conventional learning environment (cfr. also the main effects) stays.

Actually, from the curriculum-analysis we learned that, due to the structure of the curriculum, the results of the students in the PBL environment at the end of Year 1 need to be compared with the results of the students in the conventional learning environment at the end of Year 2. At that moment, both groups have had a complete introduction to macroeconomics. Comparing these two, one can see that the first group

scores higher than the latter. This difference seems almost to disappear in the following year(s).

4.1.2.2 True-score

Figure 4 gives a plot of the mean number of correct scores in function of the learning environment and the expertise-level. In this plot also the results of the pre-test are depicted, however these are not included in the analysis of variance.

Table 2: 2 x 3 Analysis of Variance of the Number of Correct Scores on the Knowledge Test.

	SS	df	MS	F	P
Learning env. (L)	1663.31	1	1663.31	18.25	.000
Expertise (E)	858.254	2	429.13	4.71	.010
L X E	1620.90	2	810.45	8.89	.000
Within	14671.85	161	91.129		
Total	35030.47	167			

The analysis of variance presented in table 2 shows that both the main effects and the interaction effect is significant.

The mean correct scores differ between the three levels of expertise ($F(2, 161) = 4.71$, $MSw = 91.13$, $p = .010$). The first and the second year do not differ that much, with a score of 45.46% (CI: +/- 3.19%) and 46.38% (CI: +/- 3.06%) respectively. In Years 3 and 4 the students give on average less correct answers (40.79%, CI: +/-2.51%).

There is also a significant relationship between the learning environment and the number of correct scores ($F 91, 161)= 18.25$, $p = .000$). The students of the conventional institute get at average 40.55% of the answers correct (CI: +/- 2.82%). The students of the PBL institute do significantly better with a mean score of 47.88 (CI: +/- 1.86). This difference results also in a strong practical effect size of 5.12.

Also the interaction effect is very significant ($F(2, 161)= 8.89$, $p = .000$). As shown in figure 4 the students of the PBL institute do better at the end of Year 1 with a score of 53.97% (CI: +/- 4.11%), compared with the score of 39.93% (CI: +/- 4.87%) from the students of the conventional institute. This difference is not found at the end of Year 2. At this point in time the students of the conventional institute (47.30%, CI: +/- 5.44%) score slightly better than the students of the PBL institute. In the third and the fourth year the students of the PBL institute (44.20%, CI: +/- 2.57%) do again much better than the students of the conventional institute (37.38%, CI: +/- 4.32%).

These results indicate that the students of the PBL institute know the most at the end of Year 1 and the students of the conventional institute seem to know the most at the end of the second year. This seems logical, knowing the structure of the curriculum of both institutes. In the second year, the

number of correct answers of both groups is comparable. This in spite of a decrease in the results of the PBL group compared with their results in Year 1. However, in the case of the students of the problem-based curriculum, this is one year after the study of the basic macroeconomic principles. For the students of the conventional curriculum, this is immediately after the thorough studying of macroeconomics. The students of the conventional institute score not as high in the third and the fourth year as they did in the second year. In other words, they also have a "drop" after the year of intensive study of the basic macroeconomic knowledge. The PBL students stay at the same level as in the second year.

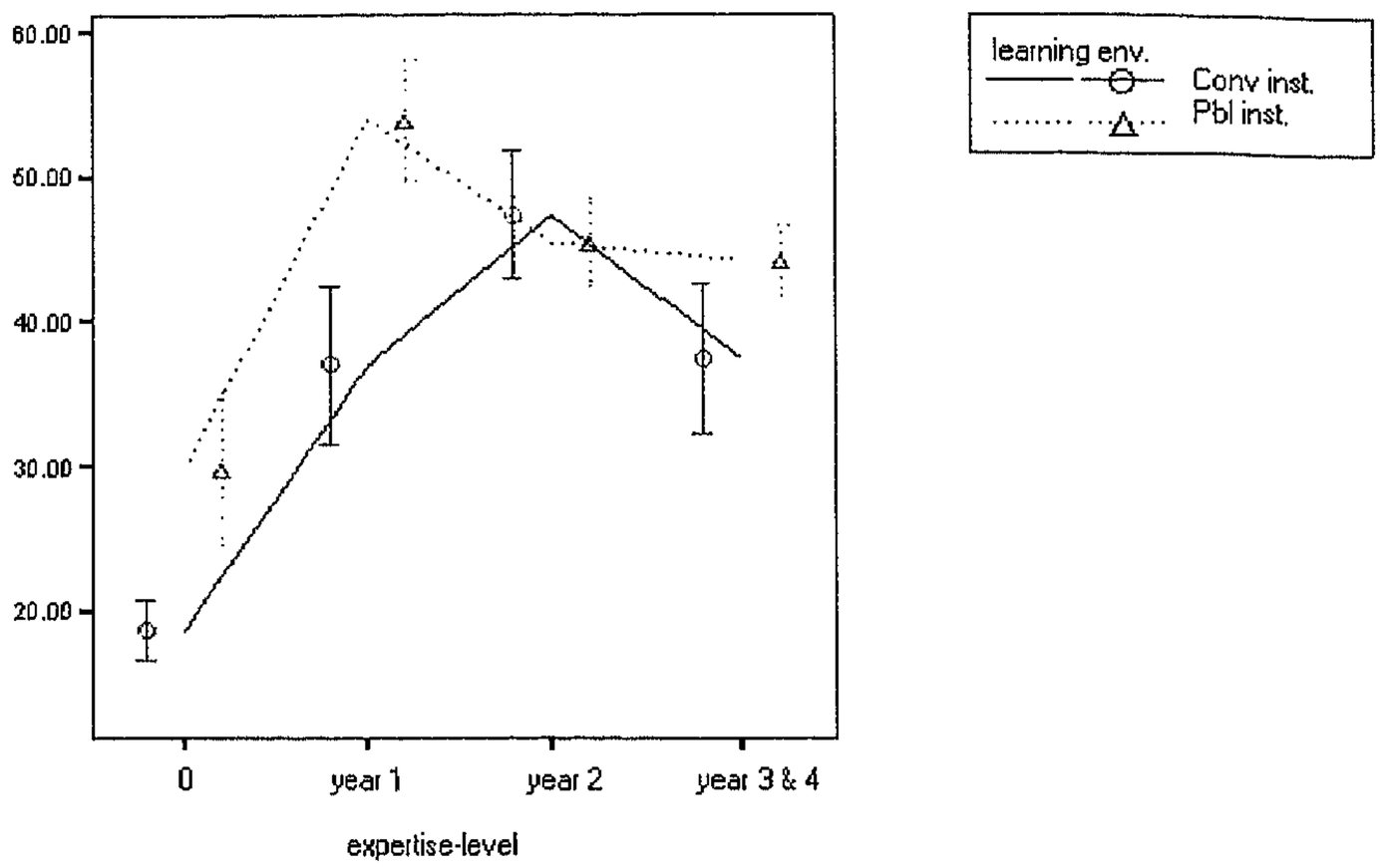

Figure 4: Mean Number of Correct Scores in Function of the Learning Environment and the Expertise-Level (the error bars show the 95% confidence intervals of the means).

4.2 Knowledge Application

4.2.1 Pre-test Scores

The average scores on the case-based test of the students of the conventional and the PBL institute are respectively 0.33 and 0.94 (with a

maximum score of 10). An independent two-sided t-test showed that these scores differ significantly (t = 4.03, df = 91, p = .000, CI: +/- 0.30). At the moment of entry the students of the PBL institute score higher than the students of the conventional institute.

Also in this case the difference in admission policy needs to be considered. The explanation that the difference in the pre-test is caused by this difference in admission policy allows us to consider the two groups as comparable from the moment the selection has also taken place in the conventional curriculum.

4.2.2 Development of the Ability to Apply Knowledge Through the Curricula

Table 3 presents the results of the 2x3 analysis of variance with two levels of learning environment and three levels of expertise. The results are interpreted using the plot of means in figure 5, the marginal means and the effect sizes.

Table 3: 2 x 3 Analysis of Variance of the Scores on the Case-Based Test.

	SS	Df	MS	F
Learning env. (L)	16.93	1	16.94	2.60
Expertise (E)	7.61	2	3.80	0.58
L X E	8.91	2	4.46	0.68
Within	1049.99	161	6.52	
Total	3409.94	167		

The results presented in table 3 indicate that there is no significant relationship between the learning environment and the results on the case-based test (F(1, 161) = 2.60, p = .109, MSw = 6.52). However, one can observe that the students of the PBL institute (4.07, CI: +/- 0.489) score on average higher than the students of the conventional institute (3.33, CI: +/- 0.76). This difference, although it is not statistically significant, results in a practical significant effect size of 1.92.

A comparison of the mean results on the different levels of expertise (controlled for learning environment) does not indicate any significant differences (F(2, 161) = 0.58, p = .559). On average the students score 4.06 (CI: +/- 0.85) at the end of Year 1. In the second year and in the third and the fourth year the tendency to get lower results is observed, respectively 3.51 (CI: +/- 0.82) and 3.52 (CI: +/- 0.67).

The plot of the means in figure 5 suggests an interaction effect. The difference between the mean scores of the students of the conventional institute (3.30, CI: +/- 1.30) and of the PBL institute (4.82, CI: +/- 1.10) at the end of the first year is larger than the small difference between the mean

scores of the students of the conventional institute (3.42, CI: +/- 1.46) and the PBL institute (3.60, CI: +/- 0.74) at the end of the second year. Whereas the difference in Year 1 is 1.52, resulting in an effect size of 2.31, there is almost no difference in Year 2 (0.19, ES = 0.25).

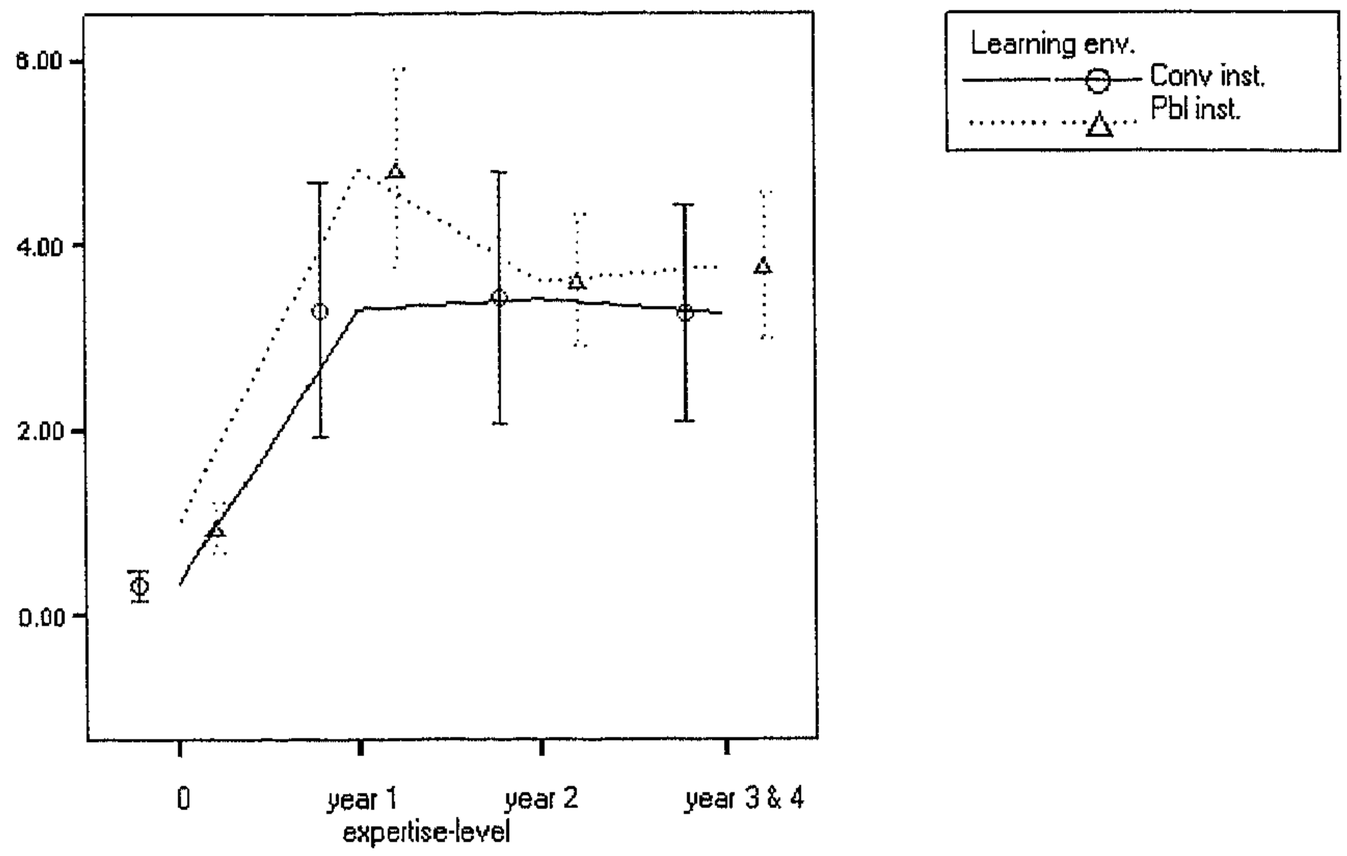

Figure 5: Mean scores on the case-based test in function of the learning environment and the expertis-level (the error bars show the 95% confidence intervals of the means).

Compared with Year 2, the difference increases in the third and fourth year. The students of the conventional institute score 3.26 (CI: +/- 1.16) and those of the PBL institute core 3.77 (CI: +/- 1.16); a difference of 0.51, resulting in an effect size of 0.87.

However, in spite of all those differences, no significant interaction effect was established ($F(2, 161) = 0.68$, $p = .506$). This analysis indicates that there are only small differences between the different levels of expertise. Also this analysis indicates that the differences between the scores of the students in the PBL environment and the conventional environment are comparable. Nevertheless, the students have a tendency to get higher scores (also the effect sizes point in that direction), especially in the first year.

The content matter necessary for solving the case was in both institutes covered in the first year of the curriculum. So this cannot be an alternative explanation for the differences found at the end of the first year. At the end of the second year no differences are found. The converging of the scores at

the end of year two is foremost a result of the decline in scores of the students at the PBL institute. At the end of Years 3 and 4 there is again a practical significant difference between the two groups of students. The tendency is for the results of the PBL students to increase again, after a decline in Year two, and that the results of the conventional students slightly decrease.

5. CONCLUSION AND DISCUSSION

In this closing part the answers the research has given to the posed research questions will be considered. Next, some critical reflections and suggestions for further research will be made.

5.1 Knowledge Acquisition

First, we wished to find the answer to the question about the extent to which students following a problem-based curriculum possess an accessible knowledge base for the subject matter compared to students who studied in the conventional way. Not only differences in learning environments were studied, but also developmental aspects, such as retention.

The students from the PBL institute have a higher mean total score on the knowledge test at every moment. This results in a statistical main effect of the learning environment, this difference is also practically very significant (ES = 3.49).

A clearer image of the knowledge base can be drawn if the number of correct answers is also taken into consideration. In general, here a practical and statistically significant higher score of the students from the PBL institute is also observed. The results indicate that whereas the students of the PBL institute know the most at the end of Year 1, the students of the conventional institute seem to know the most at the end of the second year. This is in line with the structure of the curriculum. In the second year, the number of correct answers of both groups is comparable. This in spite of a decrease in the results of the PBL group compared to their results of Year 1. However, for the students of the problem-based curriculum this is one year after the study of the basic macroeconomic principles. For the students of the conventional curriculum this is immediately after the thorough studying of macroeconomics. The students of the conventional institute do not score as high in the third and the fourth year as in the second year. In other words, they also have a "drop" after the year of intensive study of the basic macroeconomic knowledge. The PBL students stay at the same level as in the second year.

In general, the analyses with the number of correct answers suggest the same conclusion as those with the total score, only more pronounced. Also they correct for the apparent conclusion, on the basis of the total scores, that the students of the conventional institute do not make any progress after following an important macroeconomic course. This is due to the higher number of incorrect answers they also make after this period. This points to the existence of a lot of misconceptions.

These results do not confirm the stated hypotheses. The students in a problem-based curriculum score better on the test measuring knowledge acquisition from the first moment on. This conclusion is primarily based on the finding that the students of the PBL institute at the end of Year 1 score higher than the students of the conventional institute at the end of Year 2. This is the moment when they were both thoroughly confronted with macroeconomics.

With these results, this research is in line with some other research that has found positive effects of PBL on the knowledge of students (Antepohl & Herzig, 1997, 1999; Distlehorst & Robbs, 1998; Doucet et al., 1998; Lewis & Tamblyn, 1987; Richards et al., 1996; Son & Van Sickle, 2000; Tans et al., 1986; Verhoeven et al., 1998). A possible explanation for the better than expected results of the PBL students is the nature of the research instrument. Van den Bossche and colleagues (2000) ascertained that the more an instrument appeals to the retrieval strategies and skill of students, the larger the established effect of PBL. From the description of the instrument used in foregoing research we learn this instruments appeals to a certain degree to the skills of the students. This is a possible explanation for the effects found. Anyway, these results confirm the character of PBL as a learning environment that promotes the structuring and elaboration of knowledge resulting in a more accessible knowledge base.

The collected data do not permit any conclusion on the retention of the subject matter in the long-term. Both groups show a decline in their results on the test a year after their "real" confrontation with macroeconomics. A positive observation is that the students of the PBL curriculum do not experience any further decline in the third and the fourth year. However, we cannot compare these results with the knowledge development of the students in the conventional curriculum, because we have no data for two years after their "peak".

5.2 Knowledge Application

This research was also looking for an answer to the question as to whether the students in a problem-based curriculum were able to better apply their knowledge than students who studied the subject matter in the

conventional way. The analysis of the scores on the case-based test indicated no statistically significant effect of the learning environment on the scores of the students. However, the students of the PBL institute have the strong tendency to score higher at each level of expertise. Also the effect sizes in Year 1 (ES = 2.31) and in the third and the fourth year (ES = 0.87) indicate a practically significant effect. Besides that, the general effect of the learning environment is practically significant.

If we confront these results with the stated hypotheses that students in a problem-based curriculum are more capable in applying their knowledge on every moment in that curriculum, we have to conclude that the tendency in the results confirms this hypothesis. However, this tendency is not statistically significant.

One can conclude very carefully that a PBL environment is capable of promoting the application of the acquired knowledge by students through setting the adagio "knowledge as an instrument" (Norman & Schmidt, 1992) central. Already at the end of the first year the influence of this powerful, student-based learning environment is noticeable. The students of the problem-based institute score better than the students of the conventional institute, at the end of Year 2.

A remarkable phenomenon is that the students in both groups never get higher results on the test after the first year. In the PBL-group this is possibly due to the decrease in knowledge. However, the conventional group also makes no progression, although their knowledge of macroeconomics increases in the second year. Apparently, the students are not capable of applying the newly acquired knowledge; the new knowledge stays inert (Mandl, Gruber & Renkl, 1996).

5.3 Critical Reflection and Suggestions for Further Research

Below four critical comments on our own research are made, followed by suggestions for further research. The first concerns the critical success factors of PBL; the second deals with the one-sided attention given to the cognitive end of education; and the third comment points to the lack of data on long-term effects. Finally, some remarks are made on the validity of the study.

5.3.1 Critical Success Factors

The study examines the effects of a PBL learning environment. Even if the differences that were found were to be seen as a genuine effect of the learning environment (cf. infra), it remains difficult to single out those

aspects of the learning environment, which caused those differences. It also remains unclear what aspects play a crucial role in establishing a powerful learning environment. Nevertheless, such information could play an important role in successfully implementing PBL and teacher training. Further research into the critical success factors of PBL is indicated.

5.3.2 Limitation to Cognitive Effects

Although the literature on education pointed out the importance of affective and motivational elements (Boekaerts, 1993), the above study was limited to the cognitive effects of PBL, in particular knowledge acquisition and application. For this reason, it seems necessary that future research also aims at the affective and motivational aspects of learning, since powerful learning environments, in particular PBL environments, have an impact on this area as well in the sense that students have been shown to acquire a more positive attitude (Albanese & Mitchell, 1993; Lieberman et al., 1997; Percac & Armstrong, 1998; Vernon & Blake, 1993).

5.3.3 Long-Term Effects

When explaining the results, we referred to the fact that PBL students in some instances acquire less factual knowledge, but that they organize this knowledge better so that more of it is retrievable if availed upon. This implies that PBL students will possess this knowledge for the long-term and that they will also be better able to apply it after completing their studies. The results from the meta-analysis by Van den Bossche et al. (2000), which had retention period as a mediating variable, pointed in that direction. The data gathered from our own research does not permit, however, to reach a substantiated conclusion about subject matter retention. In order to chart the effects of PBL in the long term a longitudinal study is required, which continues to follow the students after having graduated.

5.3.4 Internal and External Validity

The results of this study do not lend themselves to generalization, as a number of remarks about the validity of the study will show. Statements about internal validity must be interpreted cautiously as a result of the fact that the students were not distributed at random over the experimental and control conditions. Although efforts were made to examine the comparability of the groups, the best guarantee of countering selection bias is random group distribution. This, however, is hardly possible in ecologically valid research.

In view of the specific context of the institutes in which the study was conducted and the limited range of subject matters studied, caution must also be exercised where external validity is concerned. In addition, the limited number of participants possibly endangers the external validity.

The study was a first step towards investigating the effects of PBL in various domains. The validity of the results of the study must be evaluated in the light of future similar studies (Son & Van Sickle, 2000).

REFERENCES

Albanese, M.A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine, 68*, 52-813.

Anderson, J.R. (1983). *The architecture of cognition.* Cambridge, MA: Harvard University Press.

Antepohl, W., & Herzig, S. (1997). Problem-based learning supplementing in the course of basic pharmacology-results and perspectives from two medical schools. *Naunyn-Schmiedeberg's Archives of Pharmacology, 355,* R18.

Antepohl, W., & Herzig, S. (1999). Problem-based learning versus lecture-based learning in a course of basic pharmacology: A controlled, randomized study. *Medical Education, 33* (2), 106-113.

Arts, J.A.R.M., Gijselaers, W.H., & Boshuizen, H.P.A. (2000). *Expertise development in managerial sciences: The use of knowledge types in problem-solving.* Paper presented at the Annual meeting of the American Educational Research Association, New Orleans, Louisiana.

Block De, A., & Heene, J. (1992). *Inleiding tot de algemene didactiek [Introduction to general didactics].* Antwerpen : Standaard Educatieve Uitgeverij.

Boekaerts, M. (1993). Being concerned with well-being and with learning. *Educational Psychologist, 28*, 149-167.

Campbell, D.T., & Stanley, J.C. (1963). *Experimental and quasi-experimental designs for research.* Chicago: Rand McNally.

Cooper, H.M. (1989). *Integrating research. A guide for literature reviews: Vol 2.* London: Sage Publications.

Distlehorst, L.H., & Robbs, R.S. (1998). A comparison of problem-based learning and standard curriculum students: Three years of retrospective data. *Teaching and Learning in Medicine, 10* (3), 131-137.

Dochy, F., & Alexander, P.A. (1995). Mapping prior knowledge: A framework for discussion among researchers. *European Journal for Psychology of Education, 10,* (3), 225-242.

Dochy, F., Segers, M., Gijbels, D., & Van den Bossche, P. (2002). *Studentgericht onderwijs & probleemgestuurd onderwijs: betekenis, achtergronden en effecten [Student-centered education & problem-based learning: Meaning, background and effects].* Utrecht: Lemma.

Doucet, M.D., Purdy, R.A., Kaufman, D.M., & Langille, D.B. (1998). Comparison of problem-based learning and lecture format in continuing medical education on headache diagnosis and management. *Medical Education, 32* (6), 590-596.

Dousma, T., & Horsten, A. (1995). *Tentamineren [Examinations]. Hoger Onderwijs Reeks.* Groningen : Wolters-Noordhoff.

Engel, C.E. (1997). Not just a method but a way of learning. In D. Boud & G. Feletti (Eds.), *The challenge of problem-based learning* (2nd ed.) (pp. 17-27). London: Kogan Page.

Gagné, E.D. (1993). *The cognitive psychology of school Learning* (2nd ed.). New York: HarperCollins Publishers.

Gijselaers, W.H. (1995). Perspectives on problem-based learning. In W. Gijselaers, D. Tempelaar, P. Keizer, J. Blommaert, E. Bernard & H. Kasper (Eds.), *Educational Innovation in Economics and Business I: The case of problem-based learning* (pp. 39-52). Dordrecht: Kluwer.

Gijselaers, W.H., & Woltjer, G. (1998). Cognitive science perspectives on learning and instructional quality. In D.T. Tempelaar, F. Wiedersheim-Paul & E. Gunnarsson (Eds.), *Educational Innovation in Economics and Business II. In search of quality* (pp. 345-354). Dordrecht: Kluwer.

Glaser, R. (1990). Toward new models for assessment. *International Journal of Educational Research, 14,* 475-483.

Leenders, M.R., & Erskine, J.A. (1989). *Case research: The case writing process.* Ontario: University of Western Ontario.

Lewis, K.E., & Tamblyn, R.M. (1987). The problem-based learning approach in Baccalaureate nursing education: How effective is it? *Nursing Papers, 19* (2), 17-26.

Lieberman, S.A., Stroup-Beham, C.A., Peelm J.L., & Camp, M.G. (1997). Medical student perception of the academic environment: A prospective comparison of traditional and problem-based curricula. *Academic Medicine, 72* (10), s13-s15.

Mandl, H., Gruber, H., & Renkl, A. (1996). Communities of practice toward expertise: Social foundation of university instruction. In P.B. Baltes & U.M. Staudinger, *Interactive minds. Life-span perspectives on the social foundation of cognition* (pp. 394-412). Cambridge: Cambridge University Press.

McClung, M.S. (1979). Competency testing programs: Legal and educational issues. *Fordham Law Review, 47,* 6511-712.

Norman, G.R., & Schmidt, H.G. (1992). The psychological basis of problem-based learning: A review of the evidence. *Academic Medicine, 67* (9), 557-565.

Percac, S. & Armstrong, E.G. (1998). Introducing a problem-based anatomy course in a traditional curriculum: A Croatian experience. *Medical Teacher, 20* (2), 114-117.

Poikela, E. & Poikela, S. (1997). Conceptions of learning and knowledge – impacts on the implementation of problem-based learning. *Zeitschrift fur Hochschuldidactik, 21* (1), 8-21.

Richards, B.F., Ober, P., Cariaga-Lo, L., Camp, M.G., Philp, J., McFarlane, M., Rupp, R., & Zaccaro, D.J. (1996). Rating of students' performances in a third-year internal medicine clerkship: A comparison between problem-based and lecture-based curricula. *Academic Medicine, 71*(2): 187-189.

Segers, M. (1997). An alternative for assessing problem-solving skills: The overall test. *Studies in Educational Evaluation, 23* (4), 373-398.

Segers, M., Dochy, F., & De Corte, E. (1999). Assessment practices and students' knowledge profiles in a problem-based curriculum. *Learning Environments Research, 12* (2), 191-213.

Son, B., & Van Sickle, R.L. (2000). Problem-solving instruction and students' acquisition, retention, and structuring of economics knowledge. *Journal of Research and Development in Education, 33*(2), 95-105.

Tans, R.W., Schmidt, H.G., Schade-Hoogeveen, B.E.J., & Gijselaers, W.H. (1986). Sturing van het onderwijsleerproces door middel van problemen: een veldexperiment [Guiding the learning process through problems: A field experiment]. *Tijdschrift voor Onderwijsresearch, 11,* 35-46.

Tempelaar, D. (Ed., 1993). *Handleiding Toetsconstructie [Manual testconstruction].* Maastricht: Rijksuniversiteit Limburg, Faculteit der Economische Wetenschappen.

Todd, R. (1999). Reading the future: Knowledge management 4: Towards a community of learning. *Scan, 18* (3), 34-37.

Van den Bossche, P., Gijbels, D., & Dochy, F. (2000). *Does Problem-based learning educate problem-solvers? A meta-analysis on the effects of problem-based learning.* Paper presented at the seventh EDiNEB conference, Newport Beach, USA, June.

Verhoeven, B.H., Verwijnen, G.M., Scherpbier, A.J.J.A., Holdrinet, R.S.G., Oeseburg, B., Bulte, J.A., & Van der Vleuten, C.P.M. (1998). An analysis of progress test results of PBL and non-PBL students. *Medical Teacher, 20* (4), 310-316.

Vermetten, Y.J.M. (1999). *Consistency and variability of student learning in higher education.* Ph. D. Thesis. Catholique University Brabant, The Netherlands.

Vernon, D.T.A., & Blake, R.L. (1993). Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine, 68*, 550-563.

Vilsteren Van, P.P.M., Van der Heijden, M.P., & Arts, A.R.M. (1993). *Het gebruik van casussen in cursussen van de Open Universiteit [The use of cases at the Open University].* Heerlen: Open Universiteit.

Wiel van de, M. (1997). *Knowledge encapsulation. Studies on the development of medical expertise.* Unpublished PhD. Thesis, University of Maastricht, The Netherlands.