

CHAPTER 8

Development and Evaluation of a Causal Model of Problem-Based Learning

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Traditional medical education is characterized by a 2- to 4-year period of courses in the basic sciences, followed by a 2-year period of clinical clerkships. The coursework depends largely on lectures and textbooks. During the period of clinical clerkships, it is required that students learn to apply their knowledge effectively in the evaluation and care of health problems.

Traditional medical education is regarded as very demanding. It places a heavy burden on medical students to retain knowledge that they acquired during their period of studying basic science until it is needed in clinical work (Barrows, 1984). As a consequence, students are often poorly motivated, have disappointing learning results, and are not able to use their knowledge when confronted with patients in clinical clerkships (Hamilton, 1976; Schmidt, 1983).

At McMaster University, and some years later at Limburg

University, problem-based medical programs were developed to avoid these difficulties. One of the primary goals of these programs is the development of self-directed, problem-solving physicians who are community oriented and are used to teamwork (Neufeld & Barrows, 1974). The instructional method is based upon the principle of giving students a relevant learning context. Therefore, students are confronted with problems derived from medical practice. These problems are discussed and analyzed in small-group tutorials in order to find explanations for and ways to manage the problems. Students use a problem-solving framework to develop objectives, discuss issues, formulate possible solutions, and define their own learning goals and learning needs. Within this context, students bear the primary responsibility for selecting what is for them the most appropriate medical knowledge.

If one wants to know whether an innovative educational method such as problem-based learning works or not, it becomes necessary to evaluate the program on its value and merit. Several evaluation approaches have been developed to answer questions about the effects of different educational programs. Most of these approaches differ in the ways they evaluate the success of a program. The classical approaches are concerned with questions such as "How much did the students learn?" or "How much more did they learn in fact than they would have in a more traditional program?" Typical for these kinds of evaluations is that they only focus on the outcome of the educational process. As such, they ignore the influence of the instructional and learning processes on the final student-learning results. Program improvement based on outcomes of this kind of evaluation is considered difficult or practically impossible by developers of educational programs. By contrast, today it is usually thought that evaluation must be concerned with the total context of an educational situation, that is, with its causes and its results (Lawton, 1980). Several evaluation approaches have been proposed that focus on the context of the educational situation. They are more concerned with providing information that may be suited for decision makers than are the classical approaches. Cronbach (1963), for example, suggested that evaluation should not simply be concerned with informing about success of teaching or learning, but also with information needed for careful decision making concerning a program.

According to Parlett and Hamilton (1977), evaluation should give an adequate description of the whole educational process, in order to make decisions about course improvement. Cooley and

Lohnes (1976) proposed an evaluation approach focusing on two questions: (1) What variation in achievement can be attributed to specific elements in an innovative educational program? and (2) What variation in achievement is confounded with interactions between program elements and entering abilities? This model is a synthesis of several evaluation needs. It is concerned with measuring the dimensions along which educational treatments vary, examining the confounding and unique contributions of input and treatment, deciding upon the appropriate unit of analysis, selecting valid outcome measures, and dealing with correlations within the input, process, and outcome data (Leinhardt, 1977). Cooley and Lohnes (1976) therefore use a model of classroom processes to identify and measure variables that influence the educational process. It becomes possible, then, for evaluators to provide decision makers with information about key aspects of the program. Also, program developers can be informed about the ways innovative elements in a program are actually used.

Following the ideas of Cooley and Lohnes (1976), we designed an evaluation study that tried to assess the nature of the relationships between relevant variables of the educational process and learning outcomes in problem-based learning, as implemented in the medical curriculum of the University of Limburg. In order to make suggestions for possible program improvement, the link is examined between variables of the educational process and the intended learning outcomes. We start with a description of the program and instructional method. Subsequently, a model is presented that describes the instructional process within the context of problem-based learning. A path analysis is performed to evaluate the nature of causal influences that the variables in the model exert on each other. Finally, the results are discussed in the light of program improvement.

DESCRIPTION OF THE EDUCATIONAL PROCESS

The instructional method used in this curriculum is based upon the principles of problem-based learning (Barrows & Tamblyn, 1980; Schmidt, 1983; Schmidt & De Volder, 1984). Students meet twice a week in a tutorial group (consisting of 8 to 10 students) to discuss and analyze medical problems. The task set before such a group is to analyze the problems, detect deficiencies in their knowledge, and consequently formulate learning goals and intended study activities. The tutorial group is guided by a staff member, a tutor, whose task it is to facilitate the learning process

and stimulate optimal functioning of the group. The problems are collected in a so-called block-book. This book is a guide to the students' learning activities. It contains problems, lists of learning resources, and information about scheduled activities. A block is a period of 6 weeks devoted to and organized around specific medical themes such as traumata, pain in the chest, or cancer.

It is assumed that the problem-based learning method (if implemented properly) enhances the students' interest in the subject matter as well as their study achievement. It is also believed that the quality of learning materials, block-book, and problems, strongly influences the functioning of tutorial groups, which, in its turn, is thought to influence the amount of time spent on learning and to increase the students' interest in the subject matter of the block. The tutors' task is to stimulate the functioning of the group. He or she can do so, for instance, by keeping an eye on the group's interaction process or stimulating students to deepen the level of discussion by posing questions that stimulate discussion. The level of difficulty of a block and the students' prior knowledge of the subject at hand should link up with each other adequately. If this is not the case, it is to be expected that the learning results will be suboptimal and the group's functioning will be negatively influenced. Several studies have been done to investigate certain relationships between variables of the problem-based learning model. Schmidt (1982), for instance, examined the influence of problem-based learning—as compared with that of traditional instructional methods—on achievement and intrinsic motivation. He concluded that working in small-group tutorials, using the method of problem-based learning, positively influences students' intrinsic motivation. He also found that participating in the analysis of a problem leads to a substantial activation and restructuring of existing cognitive structures. Further research was done to answer the questions of how and to what degree group functioning is directed by behaviors and actions of individual students. Bouhuijs, Gijsselaers, and Kerkhofs (1984) found that there were no students who consistently influenced their group's functioning negatively. De Volder (1981) investigated how tutor characteristics (content-expert or not) influenced group functioning and study achievement of tutorial groups. He concluded that although content-experts had a slightly more positive influence on group functioning, groups that had content-experts as their tutors did not perform better on achievement tests. Schmidt, De Volder, Gijsselaers, and Kerkhofs (1984) examined how the availability of prior knowledge influ-

ences student learning and achievement. They concluded that students who had advanced further in the study program performed better on achievement tests. This might be due to an increasing availability of medical knowledge, which facilitates the learning process.

These studies are examples of microlevel analyses of what happens to learners in problem-based learning. Each of these studies considers only a limited number of variables; taken together, these studies suggest, however, a more complex set of relations among relevant variables of the problem-based learning model.

For that reason, a model was formulated based upon these studies, and upon literature on student learning (Carroll, 1963; Cooley & Lohnes, 1976; Bloom, 1976; Haertel, Walberg, & Weinstein, 1983) and problem-based learning (Barrows & Tamblyn, 1980; Schmidt & De Volder, 1984). This model consists of input, process, and outcome variables. Input variables are prior knowledge, block-book, and tutor behavior. It is expected that these variables influence the process variables of study time and group functioning, and the outcome variables of achievement and interest in subject matter. It is also expected that the process variables influence the outcome variables. This model is displayed in Figure 8.1. The arrows indicate causal relationships between variables, lack of arrows meaning that no relationship is expected

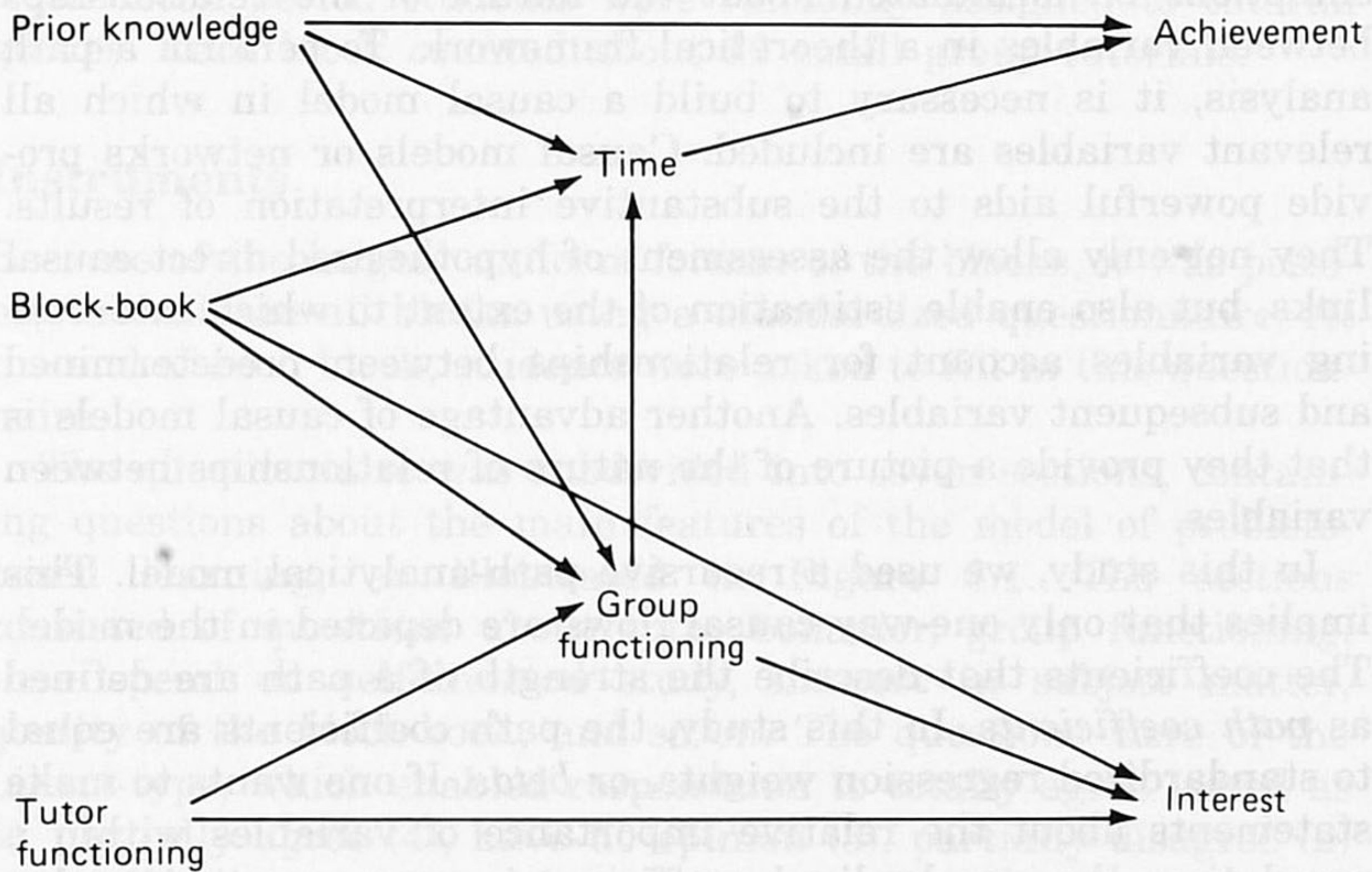


FIGURE 8.1 Model of problem-based learning.

from a theoretical point of view. The obvious method for analyzing a model like that shown in Figure 8.1 is *path analysis*. It allows for judging the plausibility of causal networks derived from a theory and to make estimates of the relative contributions of independent or intermediate variables to dependent variables.

METHOD

Statistical Analysis

A path analysis was done to assess the adequacy of the problem-based learning model. This method was developed as early as 1921 by Sewall Wright (1921, 1925). However, it was only introduced into the social sciences more recently, by Duncan (1966, 1975), Blalock (1971), Asher (1976) and Kenny (1979). A number of studies have been done using this method for exploring causal models (e.g., Covington & Omelich, 1984; Marsh, 1980; Parker-son, Lomax, Schiller, & Walberg, 1984; Stayrook & Corno, 1979; Webb, 1984). The technique of path analysis is closely related to multiple regression analysis (Kerlinger & Pedhazur, 1973; Wolfle, 1980). Both techniques focus on the analysis of interrelated sets of variables and attempt to explain the relationships between these variables. Path analysis, however, requires that explicit assumptions be formulated about the nature of the relationships between variables in a theoretical framework. To perform a path analysis, it is necessary to build a causal model in which all relevant variables are included. Causal models or networks provide powerful aids to the substantive interpretation of results. They not only allow the assessment of hypothesized direct causal links, but also enable estimation of the extent to which intervening variables account for relationships between predetermined and subsequent variables. Another advantage of causal models is that they provide a picture of the nature of relationships between variables.

In this study, we used a recursive path-analytical model. This implies that only one-way causal flows are depicted in the model. The coefficients that describe the strength of a path are defined as *path coefficients*. In this study, the path coefficients are equal to standardized regression weights, or *betas*. If one wants to make statements about the relative importance of variables within a population, the standardized coefficient is more appropriate, because it adjusts for the different scales of measurement of the

variables. However, if one wants to make comparisons across subsets of data, the unstandardized coefficients are preferable, because they are immune to the effects of different variances in the same variables that may arise due to subsetting (Asher, 1976).

Standardized regression coefficients are interpreted as the average number of standard deviations that a dependent variable y changes when an independent variable x changes by one standard deviation—when the other independent variables in the equation are held constant (Wolfle, 1980). For example, in Figure 8.2 (see p. 105), the path coefficient (p) from prior knowledge to achievement .37 suggests that achievement increases .37 standard deviations for each standard deviation increase in prior knowledge.

Subjects and Procedure

Data were aggregated from an individual level to the level of the tutorial group. This was done because achievement and judgments concerning aspects of the learning process produced by members of the same group cannot be considered independently of each other. This procedure of data aggregation was also followed in comparable studies (Cohen, 1981; Howard & Maxwell, 1980; Marsh, 1980).

During the academic year 1981/1982, 20 blocks in the first 4 curriculum years were evaluated. At the beginning of each 6-week block period students were randomly assigned to tutorial groups. Each block counted about 12 small group tutorials.

Instruments

Because of the largely uniform format of the blocks, it was possible to evaluate all blocks using a standardized questionnaire. At the end of each block, students were asked to fill in this questionnaire.

The questionnaire was subdivided into seven sections, containing questions about the main features of the model of problem-based learning, as illustrated in Figure 8.1. The sections consisted of questions about tutor behavior, group functioning, time spend on self-directed study, interest in subject matter, quality of the block-book, and so on. The questions were of the Likert-type, which enabled respondents to totally agree (rated as 5), partially agree (4), have no opinion (3), partially disagree (2) or totally disagree (1) with a statement. The questionnaire had been tested in previous research (Gijssels, 1982; Gijssels &

Schmidt, 1985), the results of which indicated that it was reliable and valid for measuring the educational process.

Interest in subject-matter was measured by two items. These referred to the degree of interest students showed with respect to the block content, and asked to what extent they worked with pleasure on the tasks. *Time spent on learning* was measured by asking students to give an estimate of the amount of hours per week spent on self-directed learning activities.

Functioning of tutorial groups was measured by 6 items of the questionnaire. These contained questions about the working procedure of the group and cooperation among group members. *Tutor functioning* was measured by 11 items. These items contained questions asking the students whether they thought the tutors were informed well enough about the block's objectives, if the tutors posed questions that stimulated discussions, and whether tutors stimulated the use of systematic working procedures.

Quality of block-book was measured by 8 items. These contained questions about the quality of the tasks (e.g., if they stimulated discussions in the group, the use of systematic working procedures, and so on). *Prior knowledge* was measured by asking students to what degree the block-content linked up with their prior knowledge.

Scales were constructed for variables that were measured by more than one item. Scale scores were computed by summing up the scores of the individual items. These scores were used for the path analysis. A test measuring their *achievement* was also administered to the students after each block. Both questionnaire and test were administered during the last session of the tutorial groups. Generally the test contained about 200 items of the true/false type. No consequences whatsoever with respect to the students' progress were attached to the outcome. The test had solely a formative purpose.

RESULTS AND DISCUSSION

Table 8.1 presents the correlation matrix for prior knowledge, block-book, tutor functioning, study time, small-group tutorials, achievement, and interest. Inspection of this matrix shows that the learning-outcome variable of interest in the subject matter is highly correlated with functioning of the small-group tutorials. Achievement is highly correlated with prior knowledge, block-book, and study time.

Four multiple regression analyses with forward (stepwise) inclusion were performed to calculate the necessary statistics for the path analysis (Nie et al., 1975). The first multiple regression analysis concerned the dependent-variable of functioning of the tutorial group and the independent variables of prior knowledge, block-book, and tutor functioning. No significant path was found between prior knowledge and group functioning ($p < .05$). Significant paths were found between block-book and group functioning ($\beta = .43, p < .01$), and tutor functioning and group functioning ($\beta = .32, p < .01$). The second multiple regression analysis was carried out between the independent variables of prior knowledge, block-book, tutor functioning, and group functioning, and the dependent variable of study time. No significant paths were found between study time and prior knowledge, group functioning or tutor functioning ($p < .05$). Block-book shared a significant path with study time ($\beta = .37; p < .01$) and group functioning shared a significant path with study time ($\beta = .24, p < .01$). The third multiple regression analysis was done with the predictors of prior knowledge and study time and the dependent variable achievement. Both paths were significant (β [prior knowledge, achievement] = .37, $p < .01$; β [study time, achievement] = .42, $p < .01$). The fourth multiple regression analysis was done with the predictors of prior knowledge, block-book, tutor functioning, and group functioning on the dependent variable of interest in subject matter at the end of the block. The path between tutor functioning and interest was not significant. The other paths were significant (β [prior knowledge, interest] = .21, $p < .01$; β [block-book, interest] = .14; $p < .01$, β [group functioning, interest] = .57, $p < .01$).

Figure 8.2 displays the path diagram of the model of problem-based learning. Only significant paths are presented. The double-curved arrows display the unanalyzed correlations between the exogenous variables (variables fully determined by causes outside the model). The arrows labeled with e_4 , e_5 , e_6 and e_7 represent the influence of the residuals. R^2 is equal to the percentage of variance attributable to or explained by the paths. Figure 8.2 shows that the dependent variables of group functioning, achievement, and interest are relatively well explained.

Before discussing the results of the path analysis, as depicted in Figure 8.2, three additional analyses are portrayed. The first analysis examines whether the observed correlations between the variables can be reproduced by the causal model. If it turns out to be possible to reproduce the observed correlations by a re-

TABLE 8.1 Construct Intercorrelations, Means and Standard Deviations ($N = 171$)

	1	2	3	4	5	6	7
1. Prior knowledge	—						
2. Block book	.51	—					
3. Tutor functioning	.19	.11	—				
4. Study time	.17	.26	-.12	—			
5. Small-group tutorials	.38	.47	.36	-.06	—		
6. Achievement	.44	.39	-.01	.48	.11	—	
7. Interest	.49	.52	.32	.01	.72	.20	—
Means	3.5	27.5	40.3	18.7	19.3	49.4	8.1
Standard deviation	.5	3.6	5.3	5.1	3.3	8.5	1.0
N of items	1	8	12	1	5	200	2

stricted model, that is, a model that does not entail all possible paths, then this may be an indication of the adequacy of the causal model. As long as all variables in the model display all possible paths between the variables, the R matrix can be reproduced regardless of the formulated causal model. Consequently, when all path coefficients are used, the reproduction of the R matrix is of no help in testing a specific theoretical model (Kerlinger & Pedhazur, 1973). A test for calculating the goodness of fit of the reproduced R matrix is the large-sample chi-square (χ^2) test (Nie et al., 1975). This test compares the actual correlations with the reproduced correlations. A nonsignificant chi-square indicates that the reproduced correlations do not deviate significantly from the observed ones. Chi-square for the problem-based learning model was equal to .70 ($Df = 9$). Chi-square was therefore nonsignificant. This means that the hypothesized model for problem-based learning showed an acceptable goodness of fit.

The second analysis focuses on how the independent variables

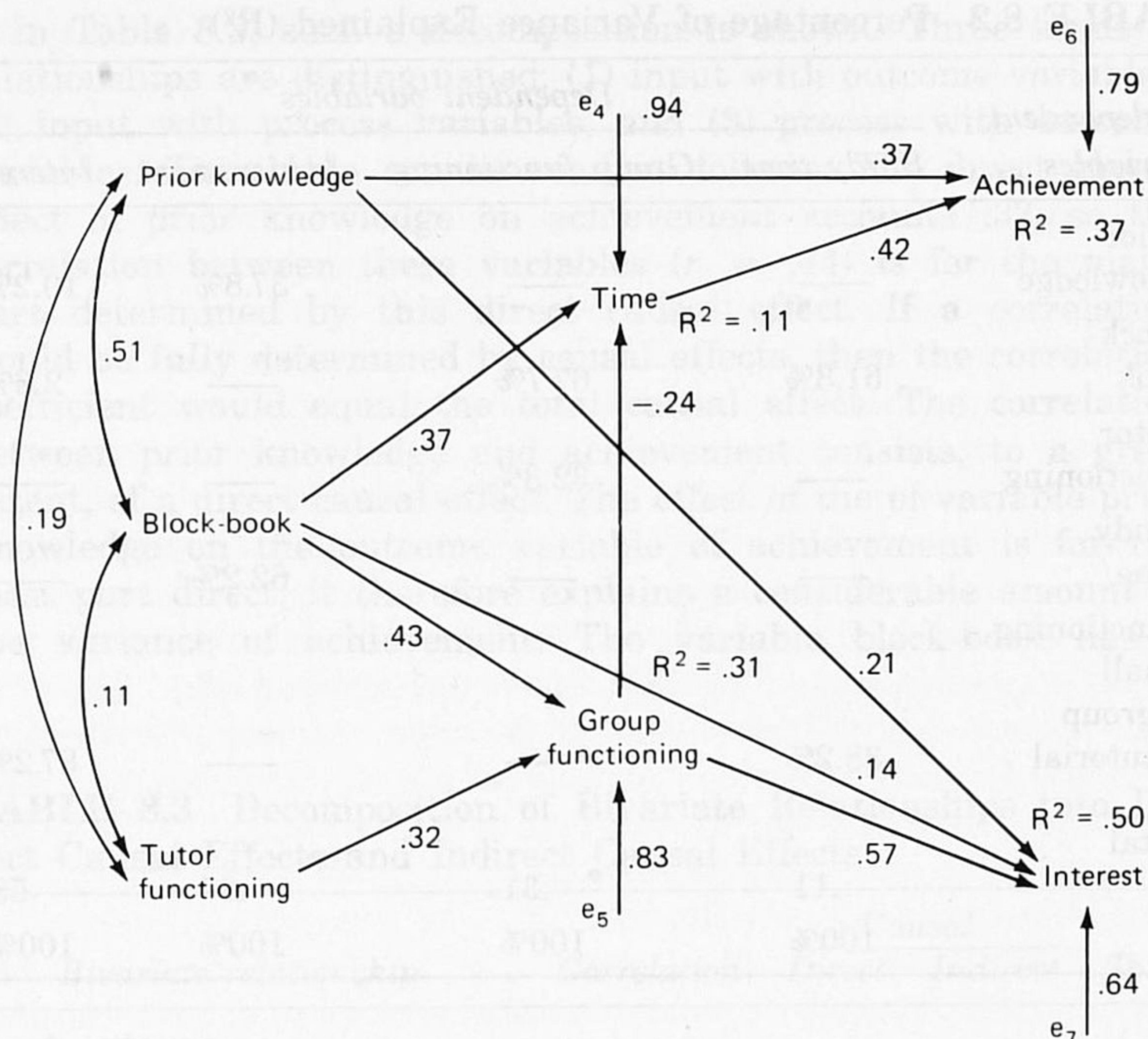


FIGURE 8.2 Path analysis of the problem-based learning model.

account for the variances of the dependent variables. This is important because it gives information about the relative influence of the independent variables on the dependent variables. For instance, it is possible to examine how the variance of achievement is explained by the variable of prior knowledge in combination with study time.

Table 8.2 shows the totals of R^2 for the dependent variables and the percentages of variance explained by the independent variables. This table can be read as follows: The variance of the variable study time ($R^2 = .11$) is explained by block-book (61.8%) and group functioning (38.2%). Variable group functioning ($R^2 = .31$) is explained by block-book (67.7%) and tutor functioning (38.2%). The variances of the process variables of study time and functioning of small-group tutorials are, therefore, to a great extent explained by the variable block-book. This gives an indica-

TABLE 8.2 Percentage of Variance Explained (R^2)

<i>Independent variables</i>	<i>Dependent variables</i>			
	<i>Study time</i>	<i>Group functioning</i>	<i>Achievement</i>	<i>Interest</i>
Prior knowledge	—	—	37.8%	10.2%
Block-book	61.8%	67.7%	—	2.6%
Tutor functioning	—	32.3%	—	—
Study time	—	—	62.2%	—
Functioning small-group tutorial	38.2%	—	—	87.2%
Total R^2	.11 100%	.31 100%	.37 100%	.58 100%

tion of the importance of this variable. The variables of achievement and interest are to a relatively low degree determined by the process variable of prior knowledge. The process variables of study time and functioning of small-group tutorials determine the greater part of the variance of the outcome variables. One can conclude from these results that the learning outcomes of problem-based learning are to a high degree determined by the contents of the block-book and by the way small-group tutorials function.

The third analysis examines the decomposition of correlations between variables in the causal model into direct and indirect causal effects. Such an analysis provides insight about the way that observed correlations between two variables can be decomposed into direct and indirect causal effects. A direct causal effect is, for instance, the path between prior knowledge and achievement. An indirect causal effect is, for instance, the relation between tutor functioning and interest: Tutor functioning has a direct causal influence on the functioning of small-group tutorials, which in its turn has a direct causal influence on interest. Therefore, tutor functioning has an indirect causal influence on interest.

In Table 8.3, such a decomposition is shown. Three kinds of relationships are distinguished: (1) input with outcome variables, (2) input with process variables, and (3) process with outcome variables. This table can be read as follows: The direct causal effect of prior knowledge on achievement accounts .37, so the correlation between these variables ($r = .44$) is for the major part determined by this direct causal effect. If a correlation would be fully determined by causal effects, then the correlation coefficient would equal the total causal effect. The correlation between prior knowledge and achievement consists, to a great extent, of a direct causal effect. The effect of the of variable prior knowledge on the outcome variable of achievement is for the most part direct; it therefore explains a considerable amount of the variance of achievement. The variable block-book has a

TABLE 8.3 Decomposition of Bivariate Relationships into Direct Causal Effects and Indirect Causal Effects

<i>Bivariate relationship</i>	<i>Correlation</i>	<i>Causal</i>		<i>Total</i>
		<i>Direct</i>	<i>Indirect</i>	
Input–outcome				
Prior knowledge–achievement	.44	.37	—	.37
Prior knowledge–interest	.49	.21	—	.21
Block-book–achievement	.39	—	.05	.05
Block-book –interest	.52	.14	.25	.39
Tutor functioning–achievement	–.01	—	–.03	–.03
Tutor functioning–interest	.32	—	.18	.18
Input–process				
Block-book–study time	.26	.37	—	.37
Block-book–group functioning	.47	.43	–.08	.35
Tutor functioning–study time	–.12	—	–.07	–.07
Tutor functioning–group functioning	.36	.32	—	.32
Process–outcome				
Study time–achievement	.48	.42	—	.42
Group functioning–achievement	.11	—	–.10	–.10
Group functioning–interest	.71	.57	—	.57

strong influence on both outcome variables. This variable has direct as well as indirect effects on the outcome variables. This result supports the hypothesis that the format of tasks and design of block-books have great influence on both process and products of problem-based learning. The tutor has no direct influence on achievement. However, the outcome variable of interest in the subject matter is indirectly (50% of the original covariation) influenced by the variable of tutor functioning. This supports the hypothesis that tutors have a considerable influence on students' subject interest.

Table 8.3 shows that the variable block-book has a great direct influence on study time and on the functioning of the small-group tutorials. Tutor functioning also directly influences the functioning of small-group tutorials to a considerable extent (89% of the original covariation). The amount of prior knowledge students have at the beginning of the block does not seem to have a significant causal effect on the functioning of tutorial groups and on study time. This result may be due to nonsignificant differences between students concerning prior knowledge. A negative path was found between the variables of group functioning and study time. This is a rather surprisingly result, because the theory of problem-based learning assumes that the better a tutorial group functions, the more time that is spent on studying. This result may be due to the trade-off between group functioning and time spent on self-directed study: The more efficiently a group proceeds, the less time that is needed to spend on independent study.

A number of objections could be raised against the relatively high correlations found in the present study. For instance, the relationship between the variables of instructional process and achievement may be interpreted as an example of the grading-lenieny bias. This bias refers to the phenomenon that students who perform better on tests are inclined to rate the instructional process more positively. This phenomenon would then explain the correlation between the study achievement and the instructional process variables. However, recent research on the validity of student ratings has cast doubt upon this explanation (Howard & Maxwell, 1980; Marsh, 1984). If this bias should exist in the path analysis shown above, a correlation between the variables of tutor functioning and study achievement (students rate tutors' functioning higher when they expect better results on the block test) might be expected. However, such a relationship was not found (the correlation between tutor functioning and achievement

amounts to $-.01$). Another reason why this kind of bias seems implausible is that the achievement tests serve formative purposes only. No decisions about students' progress are made on the basis of these tests. So it does not appear to be obvious that students should be easily influenced in their ratings of tutors and other variables by expected grades on tests.

Another source of bias that may invalidate the path analysis is the so-called halo effect. The halo effect is defined as correlations between constructs that do not represent the true correlations but that are, rather, inflated by illusory theories about the extent to which variables should covary (Cooper, 1981). If this effect exists in the path model, the values of the path coefficients may in part be due to it and therefore be higher or lower than they actually should be. For instance, the value of the coefficient of the path between block-book and discussion group may be of a given level (e.g., in this study, $.43$) because students largely attribute the way the small-group tutorial functions to the format of the problems. If students ascribed the functioning of tutorial groups to other variables, this path coefficient might have been lower. The problem of examining the effect of halo bias on the validity of this path analysis is a difficult one. The best solution would be to compare the path coefficients found with path coefficients predicted by the theory of problem-based learning. However, in this instance problem-based learning theory has not made any predictions pertaining to this type of halo effect. The only method currently available is to investigate whether the path coefficients found seem plausible within the context of the theory of problem-based learning. Indications for the plausibility of the model may be found in that it predicts the variable of achievement adequately (percentage of variance explained by the model equals 37%) and that no paths (also with regard to the value) were found that are uninterpretable or unexpected (as predicted by theory).

CONCLUSION

In this study we demonstrate an evaluation approach that focuses on the relationship between the educational process and educational outcome. This approach is based upon the ideas of Cooley and Lohnes (1976). They state that evaluation should be concerned with providing decision makers and program developers information that may be useful for purposes of course improve-

ment. Therefore, evaluation should answer questions about the relationship between achievement and specific elements of the program, and about the relationships between achievement, program elements, and entering abilities of students.

In this study, we construct a causal model of problem-based learning to identify and measure the effects of key-aspects of the program. This model is analyzed with the method of path analysis. Of primary interest in our analysis were the paths relating the learning-outcome variables of achievement and interest to the other variables. Inspection of these paths gives information about the way certain features of problem-based learning influence learning outcomes. For instance, questions about the relative influence of tutor functioning on the learning outcomes can now be answered. Of secondary interest were the paths between input and process variables. For instance, one can investigate the relationship between characteristics of the block-book and functioning of small-group tutorials. Careful and intensive inspection of the path model makes it possible to evaluate the influence of specific elements (small-group tutorials, block-books) of the model of problem-based learning.

Path analysis of data gathered to test the theory of problem-based learning showed that a causal model derived from this theory fit adequately with the empirically found relations. Further analysis have made estimates possible of the contributions of separate variables on outcome variables. Results indicate the importance of well-constructed block-books for the quality of the process of problem-based learning. As shown in the path analysis, the variable block-book has a great overall influence (direct or indirect) on the process and outcome variables. This is an important result, because it suggests opportunities for improvement of the process and outcome of problem-based learning by controlling the quality of block-books. It also suggests that educationalists working in this area should concentrate on the development of construction rules for problems. So far, these rules have been lacking (see Chapter 9). More research needs to be done on the relationship between the design of problems and learning outcomes.

Furthermore, an indication is given of the nature of the impact of tutors' behaviors on group functioning and interest. It is shown that the variance of group functioning is (32.3%; see Table 8.2) explained to a considerable extent by the tutors' functioning. The relationship between group functioning and tutor functioning was nearly entirely explained by a direct causal relationship. This

result indicates the importance of tutors' abilities to work adequately in small tutorial groups. Therefore, tutors should be trained on aspects of group dynamics.

Also, more attention needs to be paid to tutors' opinions on the effects of tutoring. Moust, de Grave, and Gijssels (see Chapter 11) showed that tutors underestimate the effects of their role on the students' learning processes. The role of prior knowledge in problem-based learning seems to be reduced to a direct influence on achievement and interest. This result indicates the importance of linking block-contents with students' prior knowledge. No significant relationship was found between prior knowledge and group functioning. This phenomenon may be due to the dominating influence of the block-book in the path analysis.

The results of this study raise an important issue for further research: The development and testing of a more elaborate and refined model of problem-based learning. Such a model could give more detailed information about actions needed to improve key aspects of problem-based medical education.

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