PROBLEM SOLVING STRATEGIES

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ABSTRACT

Problem-based learning requires the development of problem solving skills. Therefore cognitive strategies must be instructed. Some of these strategies have recently been investigated (Vernooij, 1993,c). They are part of a *knowledge base* (Ferguson Hessler, 1989), required to solve accounting problems. A knowledge base can be described in terms of Cognitive Psychology (Anderson, 1985).

As far as strategic knowledge is concerned four stages are recognized to solve a problem:
- orientation on the problem situation,
- analysis of the problem structure,
- planning of the solution,
- calculation of the answer.

Two different kinds of problems can be distinguished in business economics: fundamental problems and goal-seeking problems. Each requires its own strategy of problem solving. *Fundamental problems* can be solved by relying on the strategy of backward reasoning to reconstruct step-by-step the conceptual model (Norman, 1983) hidden in the accounting procedure. *Goal-seeking problems* require instant reconstruction of the complete conceptual model as the 'goal' is already known and the unknown is one of the original data.

However, economics and business administration use inconsistent conceptual models related to specific situations and subdisciplines. To solve a problem a student must develop a mental representation of the problem offered, using a mental model (Norman, 1983) developed earlier in the instruction process. It was found that these mental models are not an accurate reflection of the conceptual models required to solve problems. Think-aloud protocols (Ericsson and Simon, 1984) and other tests showed that students create mental representations based on *catchwords* abstracting from essential features of the quantities under consideration.

To pay attention to the development of correct mental models within an explicit cognitive strategy, instruction in economics and business administration can be organized in seven steps a group of students can go through:

1. Orientation on the problem situation of a fundamental problem;

2. Analysis of the problem situation, aimed at a discovery of the actions diagram required to solve the problem, followed by individual study of the students;

3. Confrontation of the mental models students developed to solve the problem and the conceptual model hidden in the problem;

4. Elaboration of the problem situation with related fundamental problems and goal-seeking problems, aimed at raising questions about different situations and perspectives;

5. Analysis of the related problems followed by the formulation of study-goals for individual study and problem solving;

6. Confrontation of the mental models developed by the students and the conceptual models hidden in the problems;

7. Synthesis of different approaches in a hierarchical mental model taking into account essential features, situations and subdisciplines of both economics and business administration.

This way instruction is not considered in the first place to create new mental models, but to create a continuous change and elaboration of existing mental models.

Full text of: PROBLEM SOLVING STRATEGIES

INTRODUCTION

'Once you have explained the problem, I do understand, but if I have to solve a problem like that at home, I don't know where to start'. This remark can often be heard in class. It indicates, that it is not enough to explain a problem in economics or business administration. Instructions have to be given how to tackle a problem. This requires explicit instruction in cognitive strategies available to discover the beginning of a solution. This paper reports about the results of a study in business administration from the perspective of cognitive psychology (Vernooij, 1993,c).

Little educational research is done in the field of economics and business administration. Still a lot of research is available from other disciplines like mathematics (i.e. Polya, 1954; Anderson c.s. 1981; Schoenfeld, 1989) and physics (i.e. Larkin, 1983; T. de Jong, 1986; Ferguson Hessler, 1989). This literature suggests four stages in solving a problem.

These four stages are:
- orientation on the problem situation,
- analysis of the problem structure,
- planning of the solution,
- calculation of the answer.

Each stage contains the control of each step one has done in that stage. Schoenfeld (1989) suggests to take 'evaluation' as a fifth step into account, aiming at the importance of elaborating on a certain problem once the answer on the original problem is found.

The art of problem solving requires not only information about cognitive strategies. Economics and business administration are both built on different subdisciplines, which have each their own habits and concepts. Within business administration bookkeeping, cost accounting, commercial accounting, and financial accounting have each their own vocabulary. These vocabularies are often not consistent with one another. Problem-based learning aimed at tackling a certain problem from the point of view of different subdisciplines requires a solid view on differences between these subdisciplines.

In this paper at first a description will follow of the conceptual models (Norman, 1983) that are the subject of the instruction process. Some indication is given about the differences that exist between the models used in different subdisciplines. Then, a short description is given of the way students build up a mental representation of these models. Results are mentioned, found in a survey under 155 students in secondary education. Suggestions are formulated about the development of problem-based learning in business administration. Based on a seven-steps model to master a topic, an instruction strategy is developed combining cognitive strategies and the introduction of conceptual models from different subdisciplines.

CHARACTERIZING CONCEPTUAL MODELS

Problem-based learning in economics and business administration requires that students develop problem solving skills. For that purpose, cognitive strategies must be introduced. Some of these are based on economic notions and others on non-economic notions. Although economic insight is the main goal for instruction, many study-problems contain features that allow for solutions based on insufficient economic insight.

Examples of these non-economic notions are: (1) data are presented in the sequence they must be used in the solution; (2) the main question is introduced by one or more supporting questions indicating the sequence of steps to take; (3) all the data given must be used in calculating the answer.

Study problems in economics and business administration usually have the same structure: they exist of a number of data and one or more unknowns required to compute. What is missing in this kind of problems, is the functional relationships between the data and the unknowns. An example will do to explain this habit.

EXAMPLE OF A STUDY-PROBLEM:

A merchandising company has gathered the following information about the month of June:

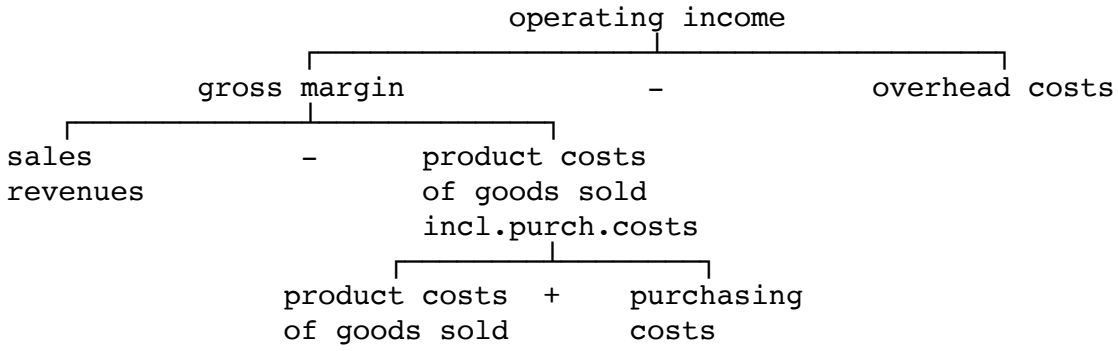
a. sales revenues	*= $ 150,000*
b. product cost of goods sold	*= $ 80,000*
c. purchasing costs	*= $ 5,000*
d. overhead costs	*= $ 30,000*

1. compute the gross margin in June
2. compute the operating income in June

To solve problems in accounting, based on economic insight, knowledge is required about the prescriptions hidden in the names of the concepts. Together the prescriptions needed for a particular problem form an *actions diagram* (Vernooij, 1990). The teacher's purpose is to have the students demonstrate their knowledge of the relationships between the data and the unknowns, by discovering a correct actions diagram to solve the problem. To find the expected answer for the study-problem presented, a knowledge structure is required as demonstrated in exhibit 1.

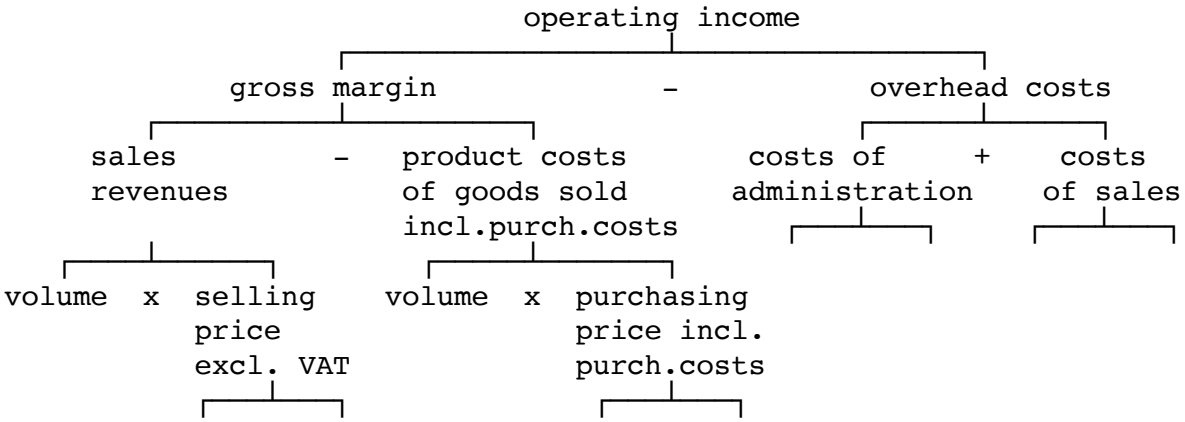
To discover the functional relationships as described in exhibit 1 students have several options. If the non-economic notions are excluded, students might try to remember a similar problem they have seen before. (But if they know the solution already the exercise is not a real problem anymore). If they don't know the solution, they might try to get the answer from a fellow-student, or they await the teachers explanation. Another possibility is to search for a description of the procedure behind the required computation. Such a procedure can be found as a conceptual model in a textbook (Norman, Gentner and Stevens, 1976; Norman, 1983).

Exhibit 1: Actions diagram of the computation of operating income in a merchandising company in the given example



Conceptual models give a description of the correct computation of important quantities in business administration. These procedures are mostly presented as examples of particular instances, but they could be presented as stories explaining how entrepreneurs are selecting data required to solve problems. Exhibit 2 shows part of a broader conceptual model that can be referred to in solving the presented study-problem. Many of the quantities mentioned can be further described as computations of subordinate quantities.

Exhibit 2: Conceptual model of computing operating income in a merchandising company

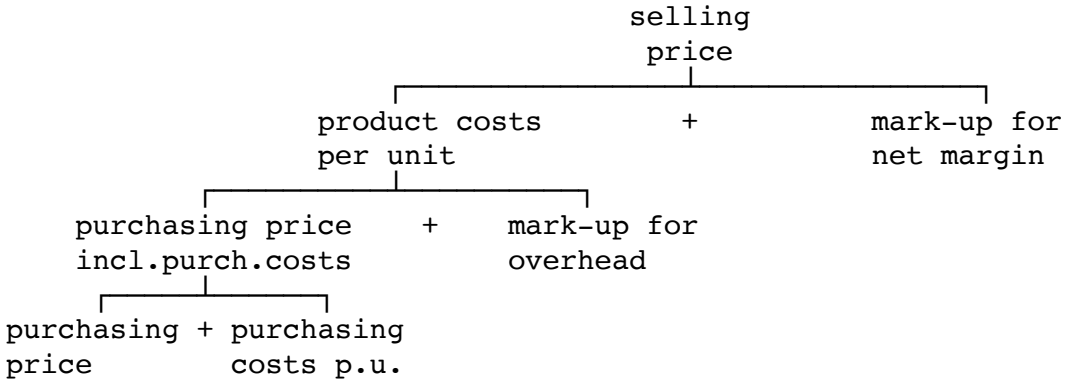


To solve a problem based on economic insight students must try to discover the conceptual model behind a study-problem, before they can transform this model in the specific actions diagram, required to solve the particular problem. Some features in this search can be mentioned. Exercises are fragments of conceptual models. Furthermore, exercises are variations on a conceptual model enforcing some modification in order to find the correct actions diagram.

The crucial difficulty in business administration is, that more and sometimes inconsistent prescriptions exist for computing the same variable. Horngren & Foster (1991, page 44) introduce three different ways to compute the 'product costs'. Thus, the *product costs* of goods sold for the yearly income statement, may well be of a different structure than the *product costs* in calculating the selling price (see exhibit 3).

Students must figure out which prescriptions to use in which situation. They must form a problem representation (Larkin, 1983) be it in economic terms.

Exhibit 3: Conceptual model of computing the selling price in a merchandising company



In solving a problem in business administration the four steps mentioned before, can be applied. At first the stage of *orientation* is aimed at recognizing the concepts used and at interpreting the situation the entrepreneur is involved in. The *analysis* of the problem structure embraces two steps. The first is the search for the conceptual model behind a certain problem. The second is the transformation of this model into an actions diagram of the presented study-problem. Once the functional relationships are clear the *planning* of the solution is possible by selecting and ordering the steps required to compute the correct answer. Then the final *calculations* can be made.

As mentioned before, Schoenfeld (1989) suggests to pay attention to the evaluation of a problem. Once a study-problem is conceived of as a part of a conceptual model, elaboration of the acquired knowledge is necessary, to master the economic model behind the specific study-problem. This elaboration can take place by presenting the same problem as part of a larger procedure, or by stating the problem in terms of another subdiscipline, or by offering some other variation of the same problem. These types of problems can be called fundamental problems as they are confirming an established conceptual model.

Another type of elaboration is possible by turning the problem upside down: one of the original data is taken as an unknown and the original unknown is presented as one of the data. This type of problem-stating is known as goal-seeking. For instance, the selling price is given as a marketing goal, but the mark-up for overhead is the unknown, or the purchasing price is unknown in a problem where as the selling is price is known.

Fundamental problems can be solved by relying on the strategy of backward reasoning. The actions diagram hidden in the accounting procedure can be discovered by logical reasoning. A student can identify himself with an entrepreneur and wonder what data are required to compute the value of a certain economic quantity like operating income in a certain period or computing the selling price of a product.

In mathematical terms the structure in exhibit 3 is a ‘zero-degree’ function: f(x) = function of (a, b, c and d).

Goal-seeking problems are different as the goal is already known and the unknown is one of the original data. For instance if the entrepreneur wants to figure out how much the overhead costs should be to attain a certain operating income. These problems require instant reconstruction of the complete actions diagram, and for that reason require a quick recognition of the conceptual model suited for the problem. As a matter of fact there are as many goal-seeking functions as there are data in a fundamental problem.

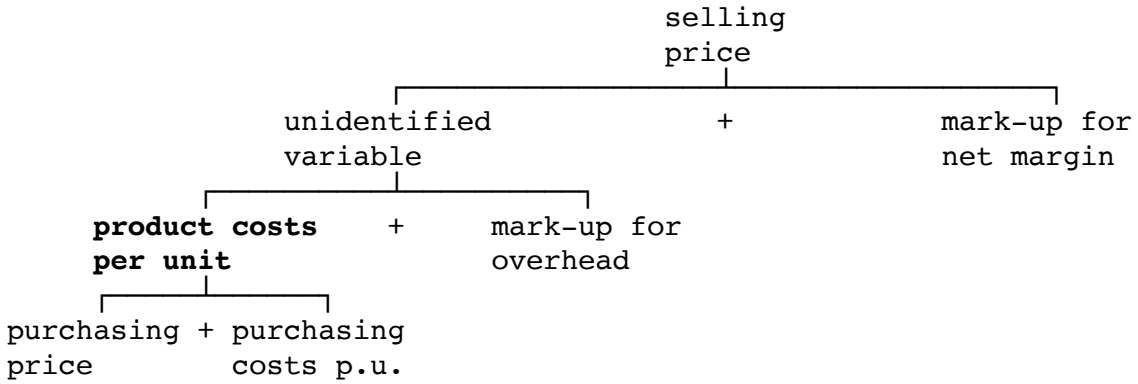
A goal-seeking problem is created by switching the relationships. In exhibit 3 there are four goal-seeking problems to be derived:
f(a) = function of (x, b, c and d)
f(b) = function of (x, a, c and d)
f(c) = function of (x, a, b and d)
f(d) = function of (x, a, b and c)

MEASURING MENTAL MODELS

The aim of instruction in business administration is to have students develop a cognitive structure, reflecting in a correct way the conceptual models taught. In solving the study-problems offered, students build up their own mental models (Norman, 1983). The question is, however, whether the mental models correspond to the conceptual models taught. To solve a new problem a student must develop a mental representation of this particular problem, using mental models developed earlier in the instruction process.

It was found (Vernooij, 1993,a) that for many students these mental models are not an accurate reflection of the conceptual models, required to solve the problems presented. Especially when a conceptual model was offered, that was inconsistent with another conceptual model taught earlier in the instruction process, students tried to integrate these models in order to create one overall structure (see exhibit 4: product costs per unit). So a larger experiment was started.

Exhibit 4: Mental model of computing the selling price in a merchandising company



A research-program has been performed in the 4th grade of secondary education. The experimental group consisted of 75 students, who received explicitly instructions in

conceptual models. The control group consisted of 80 students, who received implicit instructions in conceptual models, that means they received examples of computations instead of action diagrams (Vernooij, 1993,b).

On three topics significant differences were found in favor of the experimental group. These students performed better in separating between inconsistent models, they made less dimensional mistakes and they made less attempts to redefine the product costs of goods sold so as to make this quantity consistent with the product costs per unit (Vernooij, 1993,c).

Think-aloud protocols (Ericsson and Simon, 1984) and other tests showed that students created mental models based on *catchwords* abstracting from essential features of the quantities under consideration. They considered the distinction between 'per period' and 'per product' to be irrelevant for the relations between the concepts. This resulted in condensed knowledge structures which were unfit to solve different kinds of problems. Correct solutions in one kind of problem were related to predictable mistakes in another kind of problem.

SEVEN STEPS TO MASTER A TOPIC

To prevent the development of incorrect mental models, instruction in economics and business administration could be molded according to some fundamental principles:

- conceptual models taught should be made consistent with one another or their context should be made explicit;
- problem solving as a cognitive strategy should be made explicit;
- instruction must start with essential problems and elaborated into more complex situations (Reigeluth and Stein, 1983).
- tests should be made to find out whether the mental models developed by students, reflect the conceptual models that were presented.

To attain these goals instruction in economics and business administration can be organized in seven steps (Schmidt en Bouhuijs, 1985):

1. Orientation on the problem situation of *a fundamental problem*. An economic subject is introduced, and the relationships are stated between an essential problem and the context in which the problem has to be studied. Concepts are introduced and their meaning is defined.

2. Analysis of the problem situation. From an economic point of view a procedure is described on a verbal level to solve the chosen problem. By making a scheme of the procedure, the students discover *the actions diagram* required to solve the particular problem. Then, additional problems are presented to the students. They have to solve these problems on an individual basis.

3. Confrontation of *the mental models* students developed while solving the problems and *the bigger conceptual model(s)* hidden in the problems. If any differences exist between subdisciplines, the teacher should point at the existence of concurring conceptual models. Within a group of students the actions diagrams proposed to

solve the problem must be elaborated into conceptual models each referring to a certain subdiscipline.

4. Elaboration of the problem situation with related fundamental problems and *goal-seeking problems* on an individual level. The aim of this elaboration is to raise questions about different situations and perspectives. Real understanding starts after a problem is solved and then turned around from different perspectives (Schoenfeld, 1989).

5. Analysis of some of the related problems within a group, followed by the formulation of study-goals for individual study and problem solving within different subdisciplines. This way, another stage is started for the students, to develop their own *mental representations* of the actions diagrams hidden in newly presented problems.

6. Confrontation of the mental model(s) developed and the conceptual model(s) hidden in the problems. Definitions and actions diagrams presented in different study problems are related to the contexts in which they are presented. Some *undiscovered generalizations* can be made or *expected generalizations* can be rejected.

7. Synthesis of different approaches in a hierarchical mental model. *This synthesis* can take into account essential features, situations and subdisciplines of business administration. This must lead to a knowledge structure that is context bound.

In this way, instruction is not considered to create new mental models, but to create a continuous change and elaboration of existing mental models.

THE CONTROL OVER COGNITIVE STRATEGIES

To stress the importance of cognitive strategies, think-aloud protocols can be made by the students themselves. In groups of two, students can be asked to register each others way of tackling a problem. One is trying to solve the problem thinking aloud, the other is watching a recorder and reminding his/her colleague to keep on thinking aloud. Then the tape is used to distinguish the 4 stages in the problem solving process.

Actual stages in problem solving are confronted with the expected stages. This way the attention is not only directed towards the economic content of the problems but to the problem solving strategies as well. In this approach the stages in problem solving are both implicit (in the seven steps) and explicit (in the students activities) incorporated in the instruction process.

Research on explicit use of cognitive strategies in economics and business administration was done by Mettes and Pilot (1980), T. de Jong (1986) and Ferguson Hessler (1989), however they did research on physics education. But in business administration domain specific procedural knowledge (Anderson, 1985) takes a dominant place.

Many study problems are adapted to habits and instruction media, presently in use (Vernooij, 1993,c). They allow for solution methods that are not based on economic insight, but on non-economic strategies. The development of instruction requires new perspectives on the content of business administration as a science. Only then new ways of acquiring knowledge can come to full growth.

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