SPREADSHEETS AS A MEDIUM TO CONCEPTUALIZE MENTAL MODELS

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While solving problems in business administration, students develop a mental model of these problems. Spreadsheets can be used to conceptualize these mental models, as the computer performs the calculations once the students have formulated the relationships between the data and the unknown.

Investigations of these mental models showed mental processes, that are crucial in understanding the difficulties many students have in acquiring skills in business administration. They make it possible as well to predict the mistakes students make.

Introduction

This is the second article about a research program designed to investigate the usefulness of spreadsheets in business education. The research was part of a program aimed at developing a systematic approach to solving problems (Vernooij, 1993a). The first article (Vernooij, 1994) discussed the usefulness of spreadsheets in teaching business administration. Some technical results were presented and experiences with spreadsheets in the classroom were described.

This article is about the essential features of study problems in business administration. First, a description will be given of the business models that are part of the instruction process. Then we describe the mental processes students go through while solving problems and how spreadsheets can be used to conceptualize the mental representations students develop while solving problems.

Study problems consist usually of some data and one or more unknown quantities. The functional relationships between these quantities, however, are not explicitly given (see exhibit 1). To solve such problems based on a correct economical approach, insight is required in the prescriptions hidden in the names of the concepts.

The teacher's purpose is to have the students demonstrate their knowledge of the relationships between the data and the unknown(s). Recent research on this topic has also been done by Achtenhagen c.s. (1993).

A commercial company has gathered the following information about the month of April:

a.	sales revenues */	= £ 123,753
b.	product costs of goods sold	= £ 84,000
c.	purchasing costs	= £ 3,150
d.	overhead costs	= £ 30,000

Required:

1. compute the gross margin in April,
2. compute the operating income in April.

*/ The names are taken from Horngren & Foster (1991) and adapted to Dutch terminology.

Exhibit 1: A study problem in business administration

Conceptual models and mental models

To find the solution for a specific problem such as presented in exhibit 1, students must derive the required relationships from an established business model (see exhibit 2). Students should have the right conceptual model in mind and transform it into the required relationships for the specific study problem. This article will explore the cognitive structures students actually have in mind while solving problems.

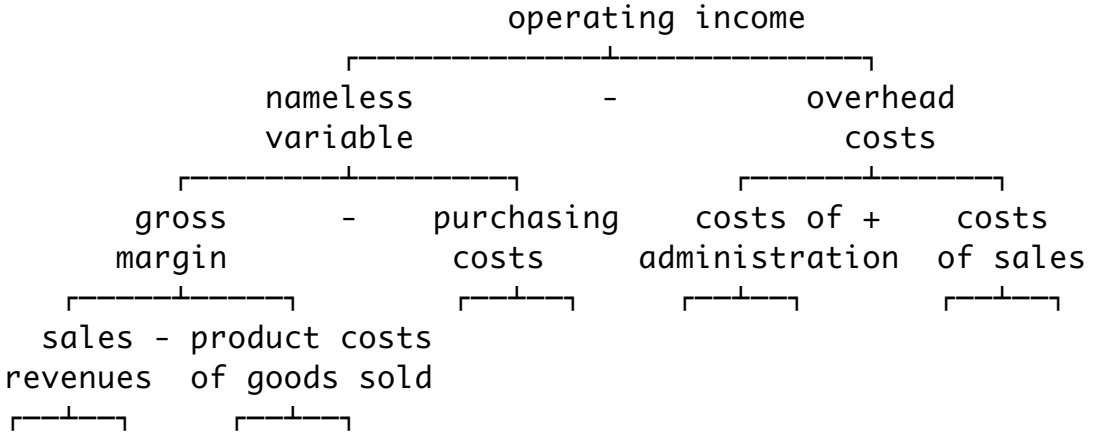

Exhibit 2: Conceptual model of computing operating income in a commercial company according to financial accounting

To elaborate further, some concepts must be introduced as they are used in cognitive psychology. Achtenhagen (1993) distinguishes eight types of knowledge, ranging from content in its diverse disciplinary structures to content as a part of the cognitive structure of ordinary people.

The most essential features are indicated by Norman (1983). He makes a clear distinction between *conceptual models* that are offered and *mental models* that students build in their minds. Those mental models can never be described directly, but they can be *conceptualized,* as will be presented in this article. Williams, Hollan, and Stevens (1983) give a conceptualization of the mental models that students in physics developed while solving problems presented in study books.

Business education is aimed at having students develop mental models which reflect in a correct way the conceptual models taught. These conceptual models are the framework of business theories. So, there are three concepts to be used: mental models, conceptual models, and business theories. Each has its counterpart at a concrete level. Study problems are specific instances of business theories.

A study problem has a frame of economic variables that can be represented in an action diagram (Vernooij, 1990), which is the counterpart of a conceptual model (see exhibit 3). Students should develop a correct representation of this action diagram in their mind, which will be indicated as a mental representation. This mental representation is the counterpart of a mental model.

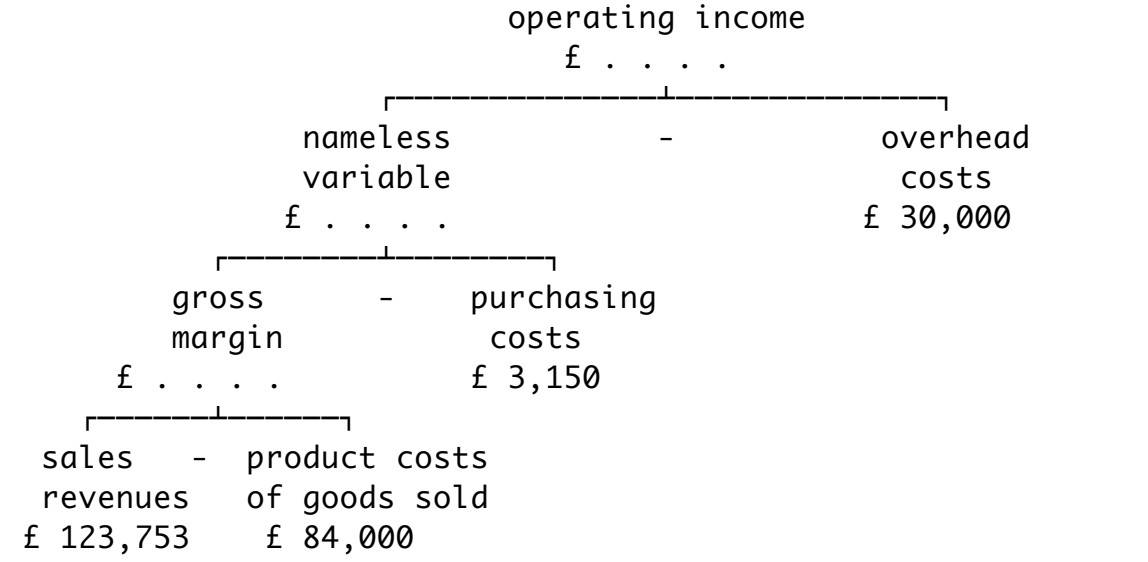

Exhibit 3: Actions diagram of computing operating income in a concrete study problem

To solve a new problem, a student must develop a mental representation of this particular problem, using the text of the study problem and one or more mental models developed earlier in the instruction process or in everyday life. Reading the description of the problem can be interpreted as combining the relationships hidden in the problem with the mental models students already have in their minds. The question then is whether the mental models really correspond to the conceptual models required to find a correct solution.

Spreadsheets can be used to force students to conceptualize their mental models (Visch, 1991; Vernooij, 1991). For the computer to calculate the correct answer, the relationships between the economic quantities must be defined explicitly in a template. A template is a worksheet within a spreadsheet program.

The writing of a well-organized template requires a clear distinction between the data to be used and the calculations to be performed. Therefore students must conceptualize their mental model by specifying the path from the data to the unknown while implementing their solution in a template.

These conceptualizations are not only important for the students, but for the teachers as well. They make explicit what students have learned and how they use this knowledge in solving problems. Persistent mistakes can be detected and traced back to incorrect mental models. They can also detect incorrect or insufficient conceptual models hidden in the problems as formulated in the study books.

Inconsistent conceptual models

The crux in managerial accounting is that more than one prescription exists 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 in financial accounting may well be of a different structure than the *product costs* in calculating the selling price in cost accounting. Students must work out which prescriptions to use in which situation. They must form a problem representation (Larkin, 1983) in economic terms.

In exhibit 2, the product costs of goods sold must be computed as: *sales volume times purchase price*. In computing the selling price, though, the product costs per unit must be calculated as indicated in exhibit 4. In this model, the product costs include the purchasing costs and a mark-up for overheads.

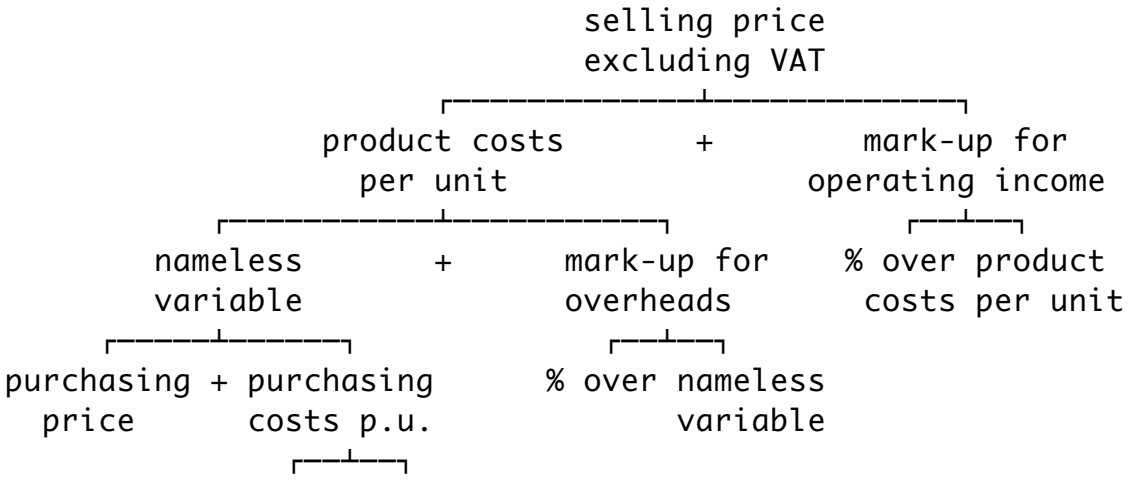

Exhibit 4: ***Conceptual model of computing the selling price in a commercial company using a mark-up for operating income***

Another difference can exist between the concept of *gross margin per period* in financial accounting and *gross margin per product* in cost accounting. As there are two mark-ups in the computation of the selling price, these can be replaced by just one mark-up named 'mark-up for gross margin' (see exhibit 5). This mark-up, however, does not include the purchasing costs per unit. Therefore, the prescription for gross margin per period and gross margin per product are not equivalent to one another.

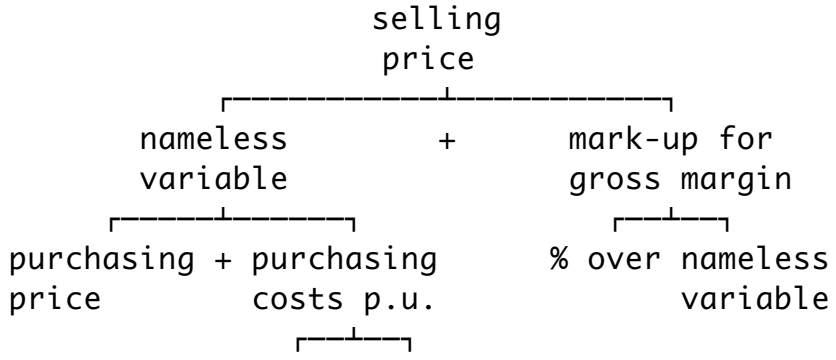

Exhibit 5: ***Conceptual model of computing the selling price in a commercial company using a mark-up for gross margin***

The idea behind the research program was that spreadsheets can be helpful in developing

economic insight. They force students to think about the structure of a problem and invite them to represent this structure in an *actions diagram* required to solve a specific problem. In this way, the attention is shifted from calculating to analyzing.

The findings of the research program

The details of the design of the research program were presented in the first article (Vernooij, 1994). Two existing classes were compared, each consisting ultimately of 14 students. One group was treated as the experimental group and the other as the control group.

The experimental group received instruction based on explicit use of conceptual models. Students were asked to make action diagrams of all the study problems before calculating the answer. The control group received instruction based on implicit use of conceptual models. As usual in business administration, they received instruction with examples of computations before they were asked to solve new problems.

The research focused on a chapter from a regular Dutch textbook (Hoogheid & Fuchs, 1987). This chapter introduced the principles of management accounting (see exhibit 4 and 5). In preceding chapters, the students were made familiar with the principles of financial accounting (see exhibit 2). The chapter under consideration consists of two sections. The first section was used to introduce the new way of teaching to the students of the experimental group.

The second section was used to introduce the use of spreadsheets. Three series of tests were presented to the students: at the start of the chapter, at the end of the first section and at the end of the second section. Exhibit 6 shows one of these problems. It was presented three times to the students, but it was with different numbers in each test. The template showing the expected calculations on problem A3 is presented in appendix 1.

A trader wants to have a template which offers him the selling price, the gross margin and the operating income of his product Flora after filling in the required data. To construct the template he has gathered some information about his business in the month of April. The lay-out of the template must be such that all the data can be changed without having to change the formulae.

In April, 2800 units of Flora are bought and 2100 units are sold. The purchase price of Flora is £ 48.00 a unit including 20% VAT. The actual overheads this month ~~was~~ were £ 30,000 excl. VAT. The purchasing costs were £ 4,200 excl. VAT. The markup for overheads is 30% on the purchase price including purchasing costs. The markup for operating income is 40% on the product costs per unit.

Make the computation of:

1. *the selling price of FLORA;*
2. *the gross margin per month;*
3. *the operating income per month;*

Exhibit 6: Study problem A as it was offered on spreadsheet

The results on study problem A are presented in table 1 and table 3. As mentioned before, the results must be compared cautiously. Students in business education are not used to taking a test before the instruction starts. Tests A1 and A2 contained just the data required to solve the problem and an instruction how to compute the product costs per unit.

These tests are similar enough to be compared. Test A3, however, contained superfluous information and lacked any instruction on how to compute the product costs per unit. Students were expected to have built their own mental model containing the prescriptions required.

Test number:	A1	A2	A3
Maximum score	7	7	7
Average score experimental group (n=14)	4.7	6.0	1.6
Average score control group (n=14)	5.6	6.1	3.1

Table 1: Results on computing the selling price in problem A in three successive tests

Test A3 shows a spectacular fall in results. Contrary to ~~the~~ expectations, the experimental group performed worse than the control group. More important was the fall in the scores of both groups. To find the possible origins of this phenomenon, an investigation was made of the kind of mental models students used in solving the problem (table 2).

Nearly half the students choose to compute the selling price by dividing the sales revenues with the volume sold in a period, which is of course a wrong computation. Sales revenues were computed with the help of mark-ups over the product costs of goods sold, instead of as a computation of volume times price. Another mistake, causing a low score, was the inclusion of Value Added Tax in the computations from the very start.

Expected model: Product Costs per unit (see exhibit 4): PC

Results:	experimental group (n=14)	8 x PC, 6 x FA.
	control group (n=14)	8 x PC, 5 x FA, 1 x X

Explanation:

PC	: computation according to the product costs per unit approach;
FA	: computation according to financial accounting: sales revenues / volume;
X	: unidentifiable approach.

Table 2: Conceptualization of mental models in computing the selling price in A3

Similar results were found in the answers about the computation of gross margin and operating income. Although the scores were not high on test A1 and A2, there still was a considerable fall in the scores on A3 (table 3).

Test number:	A1	A2	A3
Maximum score	5	5	5
Average score experimental group (n=14)	2.2	3.0	1.9
Average score control group (n=14)	1.9	3.5	2.7

Table 3: Results on computing gross margin and operating income in problem A in three successive tests

Here again, an investigation was made of the mental models used by students in solving the questions about gross margin and operating income. The scores on the questions about computing gross margin and operating income are presented in table 4.

Expected model: Financial Accounting: FA

Results:	experimental group (n=14)	11 x CA, 1 x PC, 2 x X.
	control group (n=14)	10 x CA, 3 x PC, 1 x X.

Explanation:

FA: computation according to financial accounting (exhibit 2):
gross margin = sales revenues - product costs of goods sold;

CA: computation according to cost accounting (exhibit 5):
gross margin = sales revenues - product costs of goods sold incl. purchasing costs;

PC: computation based on product costs per unit (exhibit 4):
gross margin = sales revenues - volume x product costs per unit;

X: unidentifiable approach.

Table 4: Conceptualization of mental models in computing gross margin and operating income in problem A3

The aim of the research program was to find out whether the use of spreadsheets made a contribution to an approach based on economic insight. The expectation was that the experimental group would perform better. This was not the case.

As it turned out, the students could not cope with the inconsistencies between the financial accounting approach and the cost accounting approach. This resulted in a new understanding of the mental processes students go through while solving these kinds of problems.

Catchword models

The most remarkable result is the variety of mental models that students developed as a reaction on the conceptual models presented. Most students didn't accept the conceptual models as separate entities which must be used in different situations, but rather tried to integrate them. Some ways of integrating could be expected, like the attempts to create just one prescription of calculating the product costs of goods sold.

As one student put it: "*There are several definitions of 'product costs', so one has to make a choice.*" Consequently, he introduced the concept of 'product costs per unit' in the Financial Accounting model of computing operating income and ran into the problem of deducting overhead costs twice.

Another method of integration is to create *catchword-models*. In these models, students abstract from essential economic dimensions like 'per period' or 'per product'. This finding was confirmed in a different test, which asked the students to describe the computation of some quantities like 'product costs of goods sold' and 'product costs per unit'.

Most students wrote down an *identical* description, making no difference at all between these two concepts or a *parallel* description, only making a difference in the quantity sold (table 5). A follow-up study of 155 students (Vernooij, 1993a and 1993b) confirmed this mental process. This leads to the conclusion that persistent mistakes might be caused by these inadequate cognitive structures.

exper. group		control group		
2nd	3rd	2nd	3rd	
5	7	3	2	identical: p.c. per period = p.c. per unit
7	8	7	9	parallel: p.c. per period = volume x p.c. per unit
3	-	4	3	different descriptions
-	-	-	-	correct descriptions of both

Table 5: Comparison of descriptions of 'product costs of goods sold per period' and 'product costs per unit' in a separate test.

Close examination of student 2.03

The results of student 3, member of the experimental group, are presented here as an example. Her spreadsheet template is presented in appendix 2. The structure of her solution is interesting, as it is a typical example of a catchword-model (exhibits 7 and 8).

What is remarkable, is the conflation of the conceptual model required to compute operating income with the model required to compute the selling price: the selling price is presented as sales revenues.

A second remarkable aspect is that the actual overhead costs are substituted for a markup over the whole 'purchase price including purchasing costs'. Cost accounting per unit is mixed up with financial accounting per period.

In the same way, operating income per period is computed as a percentage of the product costs of goods sold. In financial accounting, operating income is found by subtracting the costs of business from gross margin. To construct this template, the student wrote down a representation of her mental model, as is presented in exhibit 8.

Data used:

purchase price + VAT	48	per unit
overhead costs	30	%
purchasing costs (PC)	£ 4200	
volume sold	2100	units
markup operating inc.	40	%

Computations:

purchase price excluding PC:	
(purchase price + VAT) x volume sold	= £ 100,800
purchasing costs (PC)	= £ 4,200
purchase price including PC	= £ 105,000
overhead costs (£ 105,000 x 30%)	= £ 31,500
product costs	= £ 136,500
overhead costs (£ 105,000 x 30%)	= £ 31,500
operating income (£ 136,500 x 40%)	= £ 54,600
gross margin	= £ 86,100
purchase price including PC	= £ 105,000
gross margin	= £ 86,100
selling price	= £ 191,100

Exhibit 7: the approach of student 2.03

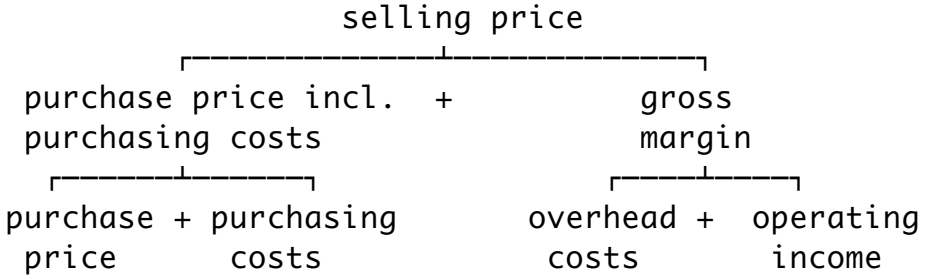

Exhibit 8: The mental representation of student 2.03 to compute operating income

No size of the economic quantities is mentioned. There is no clear distinction between quantities per unit and quantities per period. The student uses some names which belong to quantities 'per unit' (like purchase price and selling price) and some names which belong to

quantities 'per period' (like purchasing costs, overhead costs, operating income and gross margin). In her spreadsheet solution (see exhibit 7 and appendix 2), she puts in quantities per period for all the variables.

This 'catchword-model' can be applied in all situations. If one replaces selling price with 'sales revenues' and one takes the actual overhead costs, one can find gross margin and operating income by calculating top-down. However, if a markup is taken for the overhead costs and for the operating income, the selling price per unit can be computed.

The model the student has in mind contains two bright ideas. First, it avoids the whole troublesome concept of 'product costs'. The student wrote down a mental representation which makes it impossible to compute the overhead costs twice. Second, the student succeeded in building a correct model of computing the selling price with both a gross margin and a markup for operating income.

She found harmony between three conceptual models: the computation of the operating income in a period (exhibit 2), the computation of the selling price per unit with a markup for operating income (exhibit 4) and the computation of the selling price with a markup for gross margin (exhibit 5).

However, the scores for this student were very poor. No matter how clever her mental model was, she received zero points (out of 7) for question 1, zero points (out of 3) for question 2 and zero points (out of 2) for question 3.

She was not able to transform her mental model into the mental representations required for the specific situations. Actual period-quantities never are computed with a markup, and normative product-quantities are not found by dividing actual period-quantities by a volume.

By the way, textbooks are not clear on this point. Authors sometimes try to simplify reality by prescribing students to divide two actual period-quantities of last year to find a markup-percentage. This contributes to the development of misleading mental models.

Close examination of student 2.17

Many students created catchword-models. A quite surprising result was found in the experimental group. Nine of the fourteen students confuse 'product costs' with 'selling price'. They compute the selling price as the sum of the purchase price including purchasing costs and a markup for overheads. An explanation is difficult to find, although one student gave an indication of how she had been reasoning.

Exhibit 9 shows the mental representation student 2.17 wrote down. Here also, the concept 'product costs' is eliminated from her mental model. It is done by replacing 'product costs' with 'sales revenues' and calling it 'selling price'. This move makes it possible to avoid the

use of 'operating income' and 'gross margin' twice in the model. Notice the similarity between exhibit 9 and exhibit 8. Turn exhibit 8 upside down and you will find the first three levels of exhibit 9.

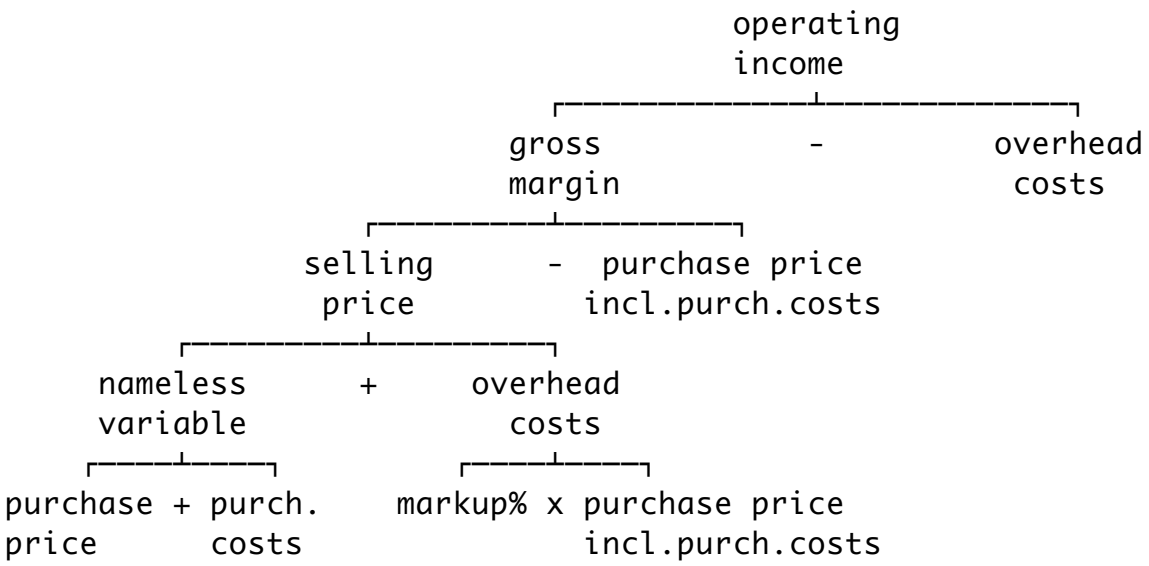

Exhibit 9: ***Catchword-model: the mental representation of student 2.17 to compute the operating income and the selling price***

In their article on 'Learning, thinking and acting in complex economic situations' in Economia, summer 1993, Achtenhagen et al. (1993) present a network structure which lies behind the list of content and goals of a curriculum. This network is a qualitative description of the concepts needed in business administration. It gives a good indication of the complexity of cognitive structures, but it is as well the ultimate representation of a catchword-model.

It does not make any allowance for quantitative aspects. Dimensions are not taken into account, and differences between disciplines in business economics are not mentioned. This network requires a transformation from a qualitative level to a quantitative level before it can be used to solve problems in business administration.

Conclusions

Exhibits 8 and 9 indicate a tendency of abstracting from the period versus product dimension, thus neglecting the differences between 'actual' and 'normative' values. At the level of catchwords, the models are quite consistent, but unsuitable for solving concrete study problems.

Persistent mistakes might be caused by inadequate mental models. To correct a mistake in a specific situation does not mean that students reorganize their mental models. The same mistake may occur again. Also, if they rearrange their mental models, they may make other mistakes as they again try to find consistency between all the economic quantities presented.

As one student put it: "*If I have to believe the instructions of this study problem, I have to compute the product costs per unit by adding up the purchase price and the purchasing costs per unit and a markup for overheads. However, it is not at all in my textbook this way*".

The strength of his own mental model made him rewrite the book. For that reason, more research is required in describing the mental processes that are going on in the minds of the students. At the same time, teachers should be aware of these processes and direct their instruction not only at the level of concrete study problems, but at the higher level of conceptual models versus mental models as well.

References

Achtenhagen, F., Ernst G.J., Preiss, P. Schunck, A., Seemann-Weymar, H. Tramm, T. and Weber, S. (1993). Reasearch in Economics Education: 'Learning, thinking, acting in complex economics situations'. *Economia*, volume 3, part 1, no. 5.

Horngren, Charles T. & Foster, George (1991). *Cost Accounting* New Jersey: Prentice-Hall.

Larkin, J.H. (1983). "The role of problem representation in Physics". In D. Gentner & A.L. Stevens (eds.) *Mental Models*. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Norman, D.A. (1983). "Some observations on mental models". In D. Gentner & A.L. Stevens (eds.) *Mental Models*. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Vernooij, A.T.J. (1990). A systematic problem approach in Business Administration. In J.M. Pieters, K. Breuer and P.R.J. Simons (Eds) *Learning Environments, Contributions from Dutch and German Research.* Berlijn: Springer Verlag.

Vernooij, A.T.J. (1991). De meerwaarde van spreadsheets in het economisch onderwijs. *TEO*, oktober.

Vernooij, A.T.J. (1993a). *Secondary education and the art of problem solving in Management Accounting*. Thesis written in dutch with a summary in english. Zutphen: Thieme.

Vernooij, A.T.J. (1993b). *Student's perception of commercial problems*. Paper for symposium 21 of the 5th EARLI Conference.

Vernooij, A.T.J. (1994). The use of spreadsheets in business education (in preparation. *Economia*, journal of AEEE).

Visch, E. (1991). Spreadsheets in het onderwijs: Hoe doe je dat?. *Didaktief,* oktober.

Williams, M.D, Hollan, J.D. & Stevens A.L. (1983). "Human reasoning about a simple physical system". In D. Gentner & A.L. Stevens (eds.) *Mental Models*. Hillsdale, N.J.: Lawrence Erlbaum Associates.

APPENDIX 1: KNOWLEDGE OF PROCEDURES: CASE STUDY A

A trader wants to have a template which offers him the selling price, the gross margin and the operating income of his product Flora after filling in the required data. To construct the template he has gathered some information about his business in the month of April. The lay-out of the template must be such that all the data can be changed without having to change the formulae.

In April 2800 units of Flora are bought and 2100 units are sold. The purchase price of Flora is £ 48.00 a unit including 20% VAT. The actual overheads this month were £ 30,000 excl. VAT. The purchasing costs were £ 4,200 excl. VAT. The markup for overheads was 30% on the purchase price including purchasing costs. The markup for operating income is 40% on the product costs per unit.

Required:
Formulate a template and save it under PROBLEMA.WKQ. Put the word 'data' on line 3 and the word 'computations' on line 13. Compute on this template:

1. the selling price of FLORA;
2. the gross margin per month;
3. the operating income per month;

Answers to case study A:

	A	B	C	--	D
1	Problem A	Name: Student			
2					
3	DATA:				
4	volume bought		2800	units	
5	volume sold		2100	units	
6	purchase price		£ 48.00	per unit	
7	overhead costs		£ 30000	this month (t.m.)	
8	purchasing costs (PC)		£ 4200	this month (t.m.)	
9	markup% overhead costs		30 %		
10	markup% operating income		40 %		
11	VAT%		20 %		
12					
13	COMPUTATIONS:	INSERTIONS:	IN DIGITS:	ON SCREEN:	
14	purchase price ex VAT	C6x100 / (100+C11)	£ 48x100/(100+20)	£ 40.00 p.u.	
15	purchasing costs (PC)	C8 / C4	£ 4,200 / £ 2,800	£ 1.50 p.u.	
16	purchase price incl. PC	C14 + C15	£ 40 + £ 1.50	£ 41.50 p.u.	
17	markup overhead costs	C9 / 100 * C16	30% x £ 41.50	£ 12.45 p.u.	
18	product cost per unit	C16 + C17	£ 41.50 + £ 12.45	£ 53.95 p.u.	
19	markup operating income	C10 / 100 * C18	40% x £ 53.95	£ 21.58 p.u.	
20	selling price excl VAT	C18 + C19	£ 53.95 + £ 4.98	£ 75.53 p.u.	
21	VAT	C11 / 100 * C20	20% x £ 75.53	£ 15.11 p.u.	
22	selling price incl VAT	C20 + C21	£ 75.53 + £ 15.11	£ 90.64 p.u.	
23					
24	sales revenues	C5 * C20	2100 x £ 75.53	£ 158,613 t.m.	
25	product costs goods sold	C5 * C16	2100 x £ 41.50	£ 87,150 t.m.	
26	gross margin	C24 - C25	£ 158,613- 87,150	£ 71,463 t.m.	
27	operating income	C26 - C7	£ 71,463 - 30,000	£ 41,463 t.m.	

APPENDIX 2: TEMPLATE OF STUDENT 2.03

	A	B	C	--	D
1	Problem A3	Student 2.03			
2					
3	DATA:				
4	purchase price + VAT		48	per unit	
5	overhead costs		30	%	
6	purchasing costs (PC)		4200		
7	volume sold		2100		
8	markup operating inc.		40	%	
9					
10	COMPUTATIONS:			ON SCREEN:	
11	purchase price excl PC		C4*C7	100,800	
12	purchase price incl PC		C11+C6	105,000	
13	overhead costs		C12/100*C5	31,500	
14	product costs		C12+C13	136,500	
15	operating income		C14/100*C8	54,600	
16	gross margin		C13+C15	86,100	
17	selling price		C12+C16	191,10O	