

Developing Robust Computer Assisted Learning Systems

Kristian Nihtilä, Christoffer Sundqvist, Kenneth Söderlund, and Ralf Östermark
Department of Business Administration
Åbo Akademi
krnihtil@abo.fi, csundqvi@abo.fi, ksoderlu@abo.fi, and rosterma@abo.fi

Abstract

In the paper we present a computer-based learning system created at Åbo Akademi University, in the department of Business Administration for graduate level students in Accounting and Finance. The system was built using clarity, simplicity, robustness and maintainability as the key design criteria. The system turned out to have great potential in a practical class room experiment, providing fruitful guidelines for future development of computer assisted learning systems in accounting, economics and finance.

Keywords

computer assisted learning, computer-based teaching, multimedia in accounting and finance

1. Definition of the Terms CAL and CAT

In its purest form, computer-assisted learning (CAL) is carried out by an interaction between a sophisticated program and the student(s), with no human teacher being involved. In Computer Assisted Teaching (CAT) the teacher merely uses the computer as a sophisticated presentation tool in which he or she can combine different media into one multimedia. Traditionally, the term CAL has also been widely used to describe what we mean by CAT.

For most cases the computer cannot totally replace the teacher but there is a lot to be gained by using them as learning aids. We think that by combining these two approaches the quality of the education can be significantly improved.

2. Problem-based Learning

Problem-based learning (Ricchetti, 1995) is an educational strategy designed to:

- maximise active student participation in the learning process;
- foster student problem solving and self-education skills;
- enhance student self-assessment;
- increase student communication skills; and
- improve student abilities to access and utilise information resources.

Problem-based learning has been used for a long time, but with the new possibilities computers give us, CAL / CAT-enhanced, problem-based learning (PBL) can be taken to new dimensions.

The main goal of PBL is to create an active student-centred learning environment through the use of relevant problems or cases. Each problem should be carefully chosen to fit the student's skill level without being neither too easy nor too difficult. It is very important to give the students such problems that it is possible for them to make continuous progress towards the solution and thereby keep the student interested, motivated and activated.

According to Waldham (1995), PBL is accomplished through the study of a case or problem in a stepwise fashion.

1 Presentation of new data

A case is usually presented as a written description of scenes and circumstances taken from a real-world situation. The case should be presented through 'progressive disclosure' of new information.

2 Analysis of the data

After receiving the data concerning the case student must analyse the information according to his / her skills and previous experience. This is usually done in a group of students where the students can share their experience and opinions.

3 Formulation and testing of hypotheses

The next step is to try to formulate hypotheses that explain the circumstances as they have been described. This step can also be enhanced by discussion in small groups. This stage often requires the student to identify his / her areas of ignorance and to make further investigations.

4 Adjusting the hypotheses

The last step is to adjust the hypotheses and, if new information has been revealed, reiterate the problem-solving process.

3. Simulation

Computer programs can be effectively used to simulate real-world problems occurring in economics. For instance, you can simulate the future cash flow changes of a big company and see how different input values will affect the profit of the company. By bringing computers into problem-based learning, one can greatly reduce the work usually associated with real-world problems. Computers with the right programs can even make totally new problems feasible to solve, e.g. by using simulation. Although we suspect that learning never will happen without some hard work from both the students and teachers, it should be noticed that computers usually take care only of the boring repetitious stuff, while letting the students concentrate on the main problem, focusing on the creative issues in the learning process. It has been said by Brennan (1991) that 'If the machines can multiply, integrate, fourier-analyse and so on, why should the student have to do these things?' Is it not a carefully concealed truth about CAL that most of the time the medium, CAL, is the real message.

Also O'Connell (1984) has expressed this well by stating that 'it is something of an anachronism that computers are used so extensively to develop skills which have become less important because of computers. Should we not use the computer to develop skills which the computer has not acquired'.

These ideas fit well with problem-based learning concepts where we can use computers to take care of the underlying mathematics in a complex problem and let the student concentrate on finding the right solution. Figure 1 provides an example on optimal firm planning, where the critical firm decisions are at focus, and where the boring task of calculating the financial statements including ratios, cash flows, etc., are left for the computer. The main purpose is to let the student learn the impact of financial decisions on the financial statements and not to calculate them. (The financial statements resulting from the decisions given a set of financial constraints have been suppressed for convenience.)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Solved: 4.9.1995 13:31													
2									PERIOD:	5	6	7	8	9
3	Netincome	177.11	SAVE RESULT	OPTIMIZE	LATEST SOLUTION	CHANGE DEFAULTS	NewFirm		Optimal cash	0.00	0.00	0.00	0.00	0.00
4									Actual Cash	0.00	0.00	0.00	0.00	0.00
5									Maximal Sales Volume	910.66	953.83	1307.51	1290.09	1490.94
6									Optimal Sales Volume	733.25	787.92	1307.51	1290.09	1490.94
7									Actual Sales Volume	733.25	787.92	1307.51	1290.09	1490.94
8									Maximal Production	810.66	776.43	1141.61	1290.09	1490.94
9	Decision variables		5	6	7	8	9		Optimal Production	810.66	776.43	1141.61	1290.09	1490.94
10									Actual Production	810.66	776.43	1141.61	1290.09	1490.94
11	1: Sales	733.25	787.92	1307.51	1290.09	1490.94			Minimal Depreciation	64.68	61.95	91.09	102.93	118.96
12	2: Production	810.66	776.43	1141.61	1290.09	1490.94			Optimal Depreciation	64.68	61.95	91.09	102.93	118.96
13	3: New debt	0.00	0.00	145.44	165.50	172.04			Actual Depreciation	64.68	61.95	91.09	102.93	118.96
14	4: Amortization	48.00	44.16	52.26	61.32	70.18			Minimal Equity/Liabilities	1.00	1.00	1.00	1.00	1.00
15	5: Investments	0.00	19.16	547.56	288.54	370.01			Optimal Equity/Liabilities	1.00	1.03	1.00	1.00	1.00
16	6: New issues	14.30	14.30	14.30	14.30	14.30			Actual Equity/Liabilities	1.00	1.03	1.00	1.00	1.00
17	7: Dividends	6.44	6.59	6.73	6.87	7.02			Maximal New Issues	14.30	14.30	14.30	14.30	14.30
18	8: Depreciation	64.68	61.95	91.09	102.93	118.96			Optimal New Issues	14.30	14.30	14.30	14.30	14.30
19	9: Dividend deviation (Divdiff)	0.00	0.00	0.00	0.00	0.00			Actual New Issues	14.30	14.30	14.30	14.30	14.30
20	10: Equity deviation (EKdiff)	0.00	0.00	0.00	0.00	0.00			Maximal Dividend	30.87	6.59	189.82	257.09	392.13
21	11: Debt-Equity deviation (D/Ediff)	0.00	0.00	0.00	0.00	0.00			Minimal Dividend	6.44	6.59	6.73	6.87	7.02
22	12: Repayment deviation (REPdiff)	0.00	0.00	0.00	0.00	0.00			Optimal Dividend	6.44	6.59	6.73	6.87	7.02
23	13: Max dividend deviation (MAXdivdf)	0.00	0.00	0.00	0.00	0.00			Actual Dividend	6.44	6.59	6.73	6.87	7.02
24									Equal Amortization	48.00	44.16	52.26	61.32	70.18
25	Actual penalty variables:								Optimal Amortization	48.00	44.16	52.26	61.32	70.18
26	Divdiff								Actual Amortization	48.00	44.16	52.26	61.32	70.18
27	EKdiff								Optimal fixed assets	1013.32	970.53	1427.01	1612.62	1863.67
28	D/Ediff				0.00	0.00	0.00		Actual fixed assets	1013.32	970.53	1427.01	1612.62	1863.67
29	MAXdivdf			0.00					Optimal long term debt	552.00	507.84	601.02	705.20	807.06
30	REPdiffm			0.00	0.00	0.00	0.00		Actual long-term debt	552.00	507.84	601.02	705.20	807.06
31														
32	Inventory volume	16.666667	7.9439252	7.8703704	8.0882353	100			Inventory volume	177.40	165.91	0.00	0.00	0.00

Figure 1. This is a strategic firm planning model in MS Excel 5.0 for optimal decision making, which allows students to simulate the outcomes of different financial decisions.

4. The Pedagogical Aspects of CAL

The learning process itself can be described along two dimensions (Hanhimäki, 1991)—the way it is organised and the mental model it gives. A program with a passive learning approach describes events and the student is supposed to learn or absorb them. An active learning approach lets the student develop a personal mental model and try out its adequacy. The program can also be differentiated according to the sequence in which the subject is taught. In a sequential learning process the action is broken down into small sequences, which are taught and practised separately (modular learning). When the learning process is an integrated process the student is allowed to create an integrated mental model and in that way understand the whole as a system. A model of holistic learning is given in figure 2. As we can see, active and sequential learning processes have not been combined in figure 2, because that would not be natural. When learning actively people tend to develop integrated mental models.

--	--	--

Learning process	Passive	Active
Sequential	Behavioural	
Integrated	Preorganiser	Action theory

Figure 2. Dimensions of the learning process.

Learning consists of assimilation and the proportioning and organising of concepts by the student (Ausubel, Novak and Hanesian, 1978). Learning new topics can be facilitated by pointing out the primary concepts of the subject at the beginning. This can be done by a preorganiser, a predescription or an analysis of the teaching material. The learning process advances deductively by repeating, practising and providing feedback for the student.

The effectiveness of multimedia and more traditionally structured CAL programs is highly dependent on the student's previous skills and experience, both concerning the subject and using computers as a tool for learning. Also the degree to which the media allows interaction affects the student's understanding of a subject. As mentioned above, a highly interactive media supports development of mentally integrated models. It is all a bit like the effective use of libraries—the more experience and knowledge of using them you have, the better you exploit the accumulated knowledge you can get there. Multimedia cannot guarantee learning, so a great deal is still up to the student's interest and motivation. However, it can stimulate the student's interest and present a subject in a more versatile way than traditional teaching methods can offer. CAL programs will therefore develop useful instead of inert knowledge (Reeves, 1991). As described by Rezabek and Ragan (1989), the primary problem in designing multimedia for learning is finding a balance between pedagogical aspects and exploration possibilities.

It can be said that multimedia represents a significantly different approach to traditional methods that require people to absorb knowledge pre-packaged by others. However, multimedia has to be consciously designed to take full advantage of the advances in cognitive learning theory that have been made over past two decades.

5. Main Points to Consider when Designing CAL / CAT Systems

We will give a short summary of the goals and points we consider important when designing our computer assisted courses:

- Clarity,
- Simplicity,
- Maintainability, and
- Robustness.

5.1 Clarity

When you are dealing with multimedia it is very easy to get carried away by all different possibilities the technology gives you. Careful considerations must be taken so that the main content, the subject you want to teach, does not get lost behind the technology. The technology should be no more than a tool that helps the teachers to teach and the students to learn. The documents and models should also be self-contained, so that the students do not have to jump from one document to another in order to see the connection between different details. This structure

supports an active integrated learning process (holistic learning). However, you should try to avoid squeezing too much data on one screen. An unfortunate layout can make a reasonably straight forward subject look complicated or even frustrating.

5.2 Simplicity

Since CAL / CAT can be used in many different areas, by different people and with different experience in using computers, it is very important to make your system as easy to use as possible. If the system is awkward to use, this will probably distract both the teacher and the students from the main subject. As resort to previous knowledge in some procedures cannot be completely avoided, it is important to make clear and easily accessible instructions to overcome any potential problems.

5.3 Maintainability

Building CAL / CAT systems is usually very time consuming and therefore also very expensive. The cost of CAL / CAT systems can be reduced by designing them so that they are easily maintained, thereby reducing the cost of maintenance and increasing the lifetime of the application. At the same time, the yield to society of efficient learning may be unexpectedly high. However, it is sometimes necessary to include details that need to be up-dated, for instance, once a year. Then it could be practical to concentrate this kind of information to one section in the program, where it is easy to check its adequacy / correctness. If this kind of information is spread out it will be more complicated and time consuming to search through all the documents for possibly out-dated facts.

5.4 Robustness

Take care that your system can be used in different situations by different people. You must therefore ensure that your system can handle all different situations without crashing. This can usually only be done with good planning and extensive testing. Robustness includes also reasonable speed of the application and accessibility of all necessary documents. Currently this restricts the use of external resources through networks (internet, databases, etc.), as you can never be sure that they are functioning.

Figure 3 gives an example where we have tried to apply the principles of clarity and self-containing documents. Options are securities, which give the holder the right but not the obligation to buy (or sell) an asset to a fixed price in the future. The most commonly used formula for calculating these values was originally a heat transfer equation from physics, which Fischer Black and Myron Scholes applied on options in 1973. This is a snapshot from a model, which calculates stock option prices, i.e., an application of option theory. You can see both input and output variables as well as the underlying formulas used in the calculations. The connection between the asset price and the value of the option is revealed when trying out alternative stock / striking prices and studying their impact on the option price.

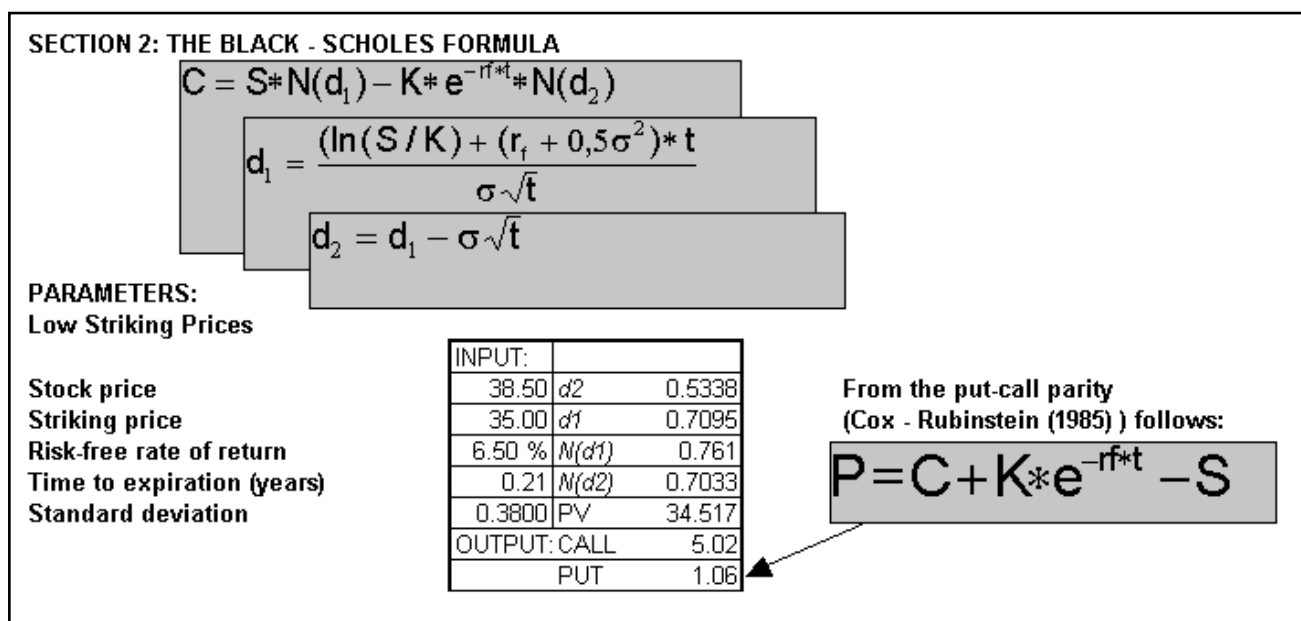


Figure 3. The Black-Scholes option pricing formula.

6. CAL—an Application

We have built some CAL applications primarily for students in advanced financial accounting. We had many of the aspects in section 1 as our guidelines, while planning and designing our applications. Especially the aspects of self-explaining models and documents and easy maintenance were stressed. At the same time the need for updating the material is kept limited (e.g. due to continuously changing dates and laws). This is quite important if the personnel changes quite frequently; for instance, the courses might be run by different persons every year.

The participants in the course could easily get access to the desired files and models, which were put on the net. In this way they were able to study all the material presented during the lectures on their own and play with the simulation models. This made it easier for the students to learn how to use the models effectively and learn the underlying theories by repetition.

We created slides in MS PowerPoint 4.0, explaining the theoretical aspects of strategic firm planning, option pricing and firm valuation. Moreover, we built simulation models applying MS Excel 5.0 and a few optimisation packages (LINGO, CPLEX, etc.) that made it possible to demonstrate how the theory could be used to solve realistic problems. We have, in other words, also included aspects of problem based learning (PBL). Initially, the students were acquainted with the theory by a slide presentation with some special effects, at the same time having a teacher answering questions and giving an even more in-depth presentation of the subject. Then the students were given cases to solve, where they could immediately apply the theories they had just learned.

We were quickly confronted with the problem that everybody who has been involved in creating multimedia can recognise—it requires more work than meets the eye. This is probably one of the biggest obstacles for schools, where those involved in such a project have to do it beside their primary job. The creation is also a continuous process, where you do and redo it as you strive for perfection.

The feedback from the students was excellent. Of course the fact that this was the first time our students experienced such an extensive use of computer technology in learning a subject must have affected the way they experienced it.

In our case the CAL presupposed a certain knowledge of accounting and statistics, but the principles could have been applied on material made for an introductory course as well.

The actual teaching comprised two intertwined parts, computer-based lectures and computer-based exercises. The lectures were kept as short as possible, 1 hour or so, with the focus on the exercises. The lectures aim at introducing the key concepts and explaining the underlying principles of the topic at issue, forming a sufficient basis for the student-driven exercises. In our opinion, the lectures serve as a general information source for the students (CAT), whereas the computer-based exercises take care of the actual learning (CAL). Since we are only at the beginning of our CAL-design, we still had to support the students actively in their exercises. However, the learning yield turned out to be significantly higher for the students participating in the course than what we have experienced previously.

7. Future Developments

The results of our efforts have been encouraging, showing obvious possibilities to shortening the gap between research and teaching. Computer-based learning tools effectively support a continuous improvement of the quality of teaching. Traditional teaching involves a lot of practical problems (e.g. learning new text books, preparing overheads, exercises, manuals, exams, modifying and reworking old material, etc.) which are effectively reduced by powerful CAT / CAL systems. One of the most important attributes of future learning systems probably is a capability to learn and modify themselves to new conditions in an ever changing environment, at the same time keeping the work load of the teacher as low as possible. It is also important that the examination is closely linked to and actually generated by the CAL / CAT-system, under due supervision of the teacher in charge.

Another important aspect, especially from the viewpoint of the student, is that the course blocks are properly linked so that repetition and 'surfing' in the CAL / CAT-based material is effectively supported.

8. Conclusions

In this paper we present our experience on CAT / CAL design and implementation in practice. We described a class room experiment, in which a computerised graduate level course in finance was successfully given to the students, demonstrating the power of CAL / CAT-design in PBL-systems. Clarity, simplicity, robustness and maintainability were the key criteria used in designing the learning system. The results demonstrate that multimedia-based learning systems certainly have a great potential in the field of economics and finance, where a multitude of calculus and computation is an inherent part of course content.

9. References

Ausubel, D. P., Novak, J. D. and Hanesian, H. (1978). *Educational psychology: A cognitive view*, 2nd ed., Holt, Rinehart & Winston, New York.

Brennan, M. (1991). *The teacher as a hero*. Paper presented at the Nordic Conference on Computer Aided Higher Education, Helsinki University of Technology, Otaniemi, Finland, August 21-23.

Hanhimäki, M. (1991). *The influence of perspective of learning on the structure of a CAL program*. Paper presented at the Nordic Conference on Computer Aided Higher Education, Helsinki University of Technology, Otaniemi, Finland, August 21-23.

O'Connell, J. A. (1984). The computer in curriculum development in Riomhairs na Scol. *Newsletter of Computer Education Society of Ireland*, Vol. 7, No. 3.

Reeves T. C. (1991). *Designing CAL to support learning: The case of multimedia in higher education*. Paper presented at the Nordic Conference on Computer Aided Higher Education, Helsinki University of Technology, Otaniemi, Finland, August 21-23.

Rezabek, R. H. and Ragan, T. J. (1989, February)., *Elaborated resources: An instructional design strategy for hypermedia*. Paper presented at the Annual Meeting of the Association for Educational Communications and Technology, Dallas, Texas.

Ricchetti, R. (1995). *Problem-based learning*. http://pegasus.cvm.msstate.edu/pbl/pbl_home.html

Waldham S. (1995). *Overview of PBL*. http://pegasus.cvm.msstate.edu/pbl/pbl_home.html