An e-Class in Action: Experiences with ICT-intensive Teaching and Learning of Discrete Dynamical Models at Secondary School

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Abstract: In 2007, a small team of university and secondary school teachers jointly developed and piloted an e-class for 4th and 5th grade students (age: 16-17yrs) at both pre-university and general vocational level. The goal was to develop and try out innovative ways of teaching mathematics that would enable schools to offer optional courses for small numbers of students. The e-class can be summarized as web-supported instruction in a blended learning approach. The instructional material consisted of the chapter on discrete dynamical models from a brand-new mathematics textbook, supplemented by investigative activities. Students could build and simulate dynamical models with the computer learning environment Coach. Instructions for learning to work with software were given through screen casts created by the teacher to gear with students' needs and made available in the Sakai-based virtual learning environment. Students got weekly on-line assignments, which they submitted digitally. At home they could get assistance from peers and the teacher in a chat room. We discuss some of the e-ingredients of the e-class and their potential for teaching and learning mathematics and science in terms of principled design approaches to multimedia learning and pedagogical arrangements. We report the experiences of the participants of the project and present the future plans based on this work.

1. Background

The design and implementation of an e-class and the future plans regarding this form of blended teaching and learning cannot been seen apart from curriculum reforms and changes in the Dutch education system that took place in secondary education in the Netherlands in the last two decades and from the reforms still under way (For details about the Dutch education system we refer to documents of the Ministry of Education, www.minocw.nl). In particular the implementation in 1998 of the so-called 'Second Stage', that is, the upper secondary education, had a strong influence because it introduced many new concepts for education and it introduced new national curricula. Until 1998 students had been free to pick their own combination of examination subjects. This free choice was replaced by a selection of one of four fixed subject combinations. These four subject combinations, called 'profiles', are: (1) Nature & Health, (2) Nature & Technology, (3) Economics & Society, and (4) Culture & Society. The first two profiles form the category of 'Nature Profiles'; the last two profiles are categorized as 'Society Profiles'. The Second Stage was adapted in 2003 (reduction of study load was one of the issues) and renewed in 2007 (introduction of new study programs). All profiles consist of a common core of subjects plus a number of specialized subjects and an optional component. The common core of subjects provides knowledge and skills of general educational value. The specialized subjects in the profile determine for which higher education studies a student can apply. In the optional part, individual accents can be laid. To enable individual learning paths in a certain profile, school examinations have been introduced next to the nationwide, written examination. In this educational setting, students are required to carry out some practical investigation tasks and one rather large, cross-disciplinary research or design assignment, called the 'Profielwerkstuk' [Profile Project]. Table 1 shows the curriculum and study load of the Nature & Technology profile in pre-university secondary education as of August 2007, when the 'New Second Stage' got implemented. This profile prepares for a university study in exact sciences and engineering.

Not only the education system and the list of curriculum subjects changed in the last decades, but also the educational goals, subject matter, teaching materials, and teaching methods underwent significant changes. This holds especially in mathematics and science education. For the context of

describing the e-class project, we can restrict the discussion to the newly introduced subjects 'Mathematics D' and 'Nature, Life and Technology' (henceforth abbreviated as NLT, but also called 'Advanced Science Mathematics and Technology' by the Steering Committee on their web site http://betavak-nlt.nl/English/)

Table 1: Curriculum and study load of the Nature and Technology profile in pre-university secondary education.

part of the study programme	Subject	study load hours
common to all profiles	Dutch	480
	English	400
	2nd foreign language (German or French) (or a classical language at a Gymnasium)	480 (600)
	Social Studies	120
	Culture and Arts (or Classical Culture)	160
	General Science	120
	Physical Education and Sports	160
compulsory part	Mathematics B	600
	Physics	480
	Chemistry	440
	Profile project	80
one subject to choose from	Mathematics D	440
	Informatics	440
	Nature, Life and Technology	440
	Biology	480
free part	at least one subject to choose freely from all school subjects with an examination	440
	(optionally, depending on the school) a subject of free choice	(400)

The optional 'Mathematics D' is only offered to students in the Nature & Technology profile and aims at deepening of understanding mathematics and at extension of mathematical knowledge and skills through separate modules. Statistics and probability theory, dynamical systems, or a topic like complex numbers are examples of extensions. The deepening comes to the surface in topics taken from a scientific or technical context such as cryptography, graph theory and discrete mathematics, optimisation, and the mathematics of traffic. 'Nature, Life and Technology' (NLT) is a new, integrated science subject offered to students in both nature profiles that aims to create coherence in the different subjects of the sciences and to make the natural sciences and technology more attractive. It is based on a modular structure with domains such as communication and navigation, health and healthcare, biomedical technology and biotechnology, earth and climate, stellar information and processes, and biophysics, biochemistry and bioinformatics. Examples of modules have titles like 'forensic evidence', 'sports records', 'partying and no hangover', 'zero-energy greenhouse', 'aerosols and clean air', 'MP3-player', 'pharmacology', and 'dynamic modelling'.

The lists of possible contents of 'Mathematics D' and NLT illustrate that these optional subjects aim to tackle the problem that (1) exact sciences have little attraction for students because the school subjects are not challenging and seem disconnected with new developments in society, mathematics, science and technology, and (2) that, as a consequence of this lack of appeal, too few students choose a follow-up study or profession in these fields.

The implementation of the new curricula has to contend with difficulties of a rather short preparatory period, a lack of modern and advanced equipment at secondary schools, and a shortage of qualified teachers who have enough scientific baggage for teaching the new mathematics and science subjects. To tackle these problems in the region of Amsterdam an initiative, called the 'its academy' (www.itsacademy.nl), was started in 2007. Within this framework, staff members from about forty secondary schools and four higher education institutes jointly design and implement the new offer of curriculum materials. Because of the real danger that not enough students would choose Mathematics D or NLT, and consequently teaching can only be done cost-effectively within a cluster of schools, the potential of e-learning in conjunction with classroom activities at cluster level and practical work in the its-labs at the higher education institutes has been examined. Table 2 shows the percentages of schools offering these new optional subjects and the percentages of students selecting these subjects in the study year 2007/2008 (Tweede Fase Adviespunt 2008). These figures must be read within the perspective that the percentage of students choosing a nature profile

increased recently to 22% and 26% for the Nature & Technology and Nature & Health profile, respectively.

In May and June 2007, a pilot study of e-classes Mathematics D with a study load of 40 study hours was carried out. About three hundred students from 4th and 5th grade (age 15-17) at both pre-university and general vocational level, from fifteen classes at four schools, participated. Only a minority of the students belonged to the envisioned group of motivated and mathematically competent students who would choose the optional Mathematics D subject in their Nature and Technology profile. However, because we thought that the new style of teaching and learning would also be relevant for mathematics courses at other levels of education, we tested the new approach with a diverse group of students to get experiences from many directions. The mathematics subject was number sequences, recursive formulas and discrete dynamical models. It was taught from a chapter in a brand-new book appearing in the largest mathematics textbook series in the Netherlands and supplemented by investigative activities on quantitative pharmacokinetics and alcohol metabolism (Heck 2007; for lesson materials, see www.science.uva.nl/~heck/research/alcohol), approximation of roots, and bouncing balls (Heck et al 2008). We discuss some of the e-ingredients of the e-class and their potential for teaching and learning mathematics and science in terms of principled design approaches to multimedia learning and pedagogical arrangements. We report the experiences of the participants of the project and present the future plans based on this work.

Table 2: Percentages of schools offering and students selecting the new subjects in 2007

subject	schools	chosen (average)	male	female
Mathematics D	71%	7%	11%	3%
NLT	38%	8%	10%	6%

2. What does an e-class look like?

Harm Houwing is an experienced mathematics teacher at the municipal comprehensive school in Schagen, North Holland, and he is also author of the mathematics textbook series 'Getal en Ruimte' concerning Mathematics B (for senior secondary education) and Mathematics D. In collaboration with six teachers from Bonhoeffercollege (Castricum), Bertrand Russell College (Krommenie) and Goois Lyceum (Bussum), and three staff members from the University of Amsterdam and the Free University Amsterdam, he designed and implemented an e-class for his 4th grade pre-university students (age: 16yrs) on the subject of discrete dynamical models. We use this course to exemplify what the e-class concept is.

One of the ideas behind the set-up of an e-class was to develop a rich electronic learning environment equipped with study guides, digitised lesson materials, software for learning and doing mathematics and science, video instructions, animations, (self-)assessments, chat functionality for students and teachers, and so on. Central is the blended approach, here considered as a combination of online learning and face-to-face education at school, in which various methods of delivery of instruction are used in such way that schools where there are only few students who choose Mathematics D (or some other optional course) are still able to offer the course effectively as a partner in a cluster of schools. Actually, the broader definition of (Heinze and Proctor 2004) for blended learning in higher education – "learning that is facilitated by the effective combination of different modes of delivery, models of teaching and styles of learning, and founded on transparent communication amongst all parties involved with a course." – seems to us more applicable to the e-class setting. We will adopt this definition, acknowledging that there is no universally accepted definition of blended learning (Whitelock and Jelfs 2003; Bonk and Graham 2006) and that there are some serious doubts about its conceptual integrity (Oliver and Trigwell 2005). In the rest of this article we look into the different modes of delivery, models of teaching, and styles of learning.

The set-up of the pilot course given by Harm Houwing was both simple and complex. Students received a preprint of the chapter on discrete dynamical models from the brand-new textbook for Mathematics D to work with. The PDF-version of this chapter and the study guide, which informs the students about their weekly assignments, were put online in the Sakai-based virtual learning environment (VLE) to which all students of his class had access. Students learned to work with number sequences and recursive formulas, and they learned to build and simulate discrete dynamical models with the computer working environment Coach (Heck et al 2009; see also www.cma.science.uva.nl), the modelling and data video version of which they had received to work with at home. Instructions for learning to use this software and other programs like Excel and the

graphing calculator were mainly given by means of screen casts that were created by the teacher and were made available in the VLE. A screen cast, a term coined by Udell (2004, 2005), is "a digital movie in which the setting is partly or wholly a computer screen and in which audio narration describes or explains the story on the on-screen action." In this way, students did not need to get separate instructions on tool use or find their ways through long manuals. Students were requested to hand in their answers to some of the online assignments through the request-and-delivery system for exercises inside the VLE: this homework could be a Word document, an Excel sheet, a Coach result file, or whatever appropriate digital document. Students got partial credit for their homework. For personal transfer of documents between a student and the teacher (for example, to get dedicated help or advice on a task, or for the simple reasons that homework could not be delivered within the scheduled timeframe), the drop box facility of the VLE was convenient. Students used the chat facility of the e-class to keep in touch with their peers and the teacher during the course: they could discuss exercises, ask each other for further information or explanation, and so on. And last but not least, students could still meet the teacher at school and ask questions, discuss homework, and so forth. Weekly meetings between teacher and students were scheduled. After all, face-to-face contact in education remains highly valued! The course ended with a written test and a computer-based assessment. Thus, the assessment of the students is in accordance with the way they had studied the subject contents.

The complexity of the e-class setting lies in the well-known fact that mere use of ICT in education does not lead to good quality of learning. The major challenge for a long time is how to find the right mix for a blended learning arrangement with regard to content, knowledge construction, communication within a regular curriculum setting (Laurillard 2002; Kerres and de Witt 2003; John and Wheeler, 2008) that leads to meaningful learning, and how to initiate, sustain, and structure interaction and enhance its quality (Hannafin 1989). In the design of the pilot e-class we have based our decisions mainly on the teachers' experiences, research-based design principles of multimedia learning (for a collection of papers see Mayer 2005), and principles of learning sciences for the design of pedagogical arrangements (for a collection of papers see Sawyer 2006). Below we exemplify this in the description of the virtual learning environment and some of the e-ingredients.

Figure 1 shows the opening screen of an e-class after logging in. It is kept as simple as possible so that navigation through the instructional environment is easy. On the left-hand side is the list of facilities; from top to bottom they are the link to the home page of the course, the study guide, the agenda, the archive of announcement, the documents related to the course (also Coach files and tutorial video clips to work with), a discussion forum, the list of assignments, the list of grades, the drop box, the chat room, e-mail, and a quick link to the web site of the school. The midsection of the home page is used for general information and on the right-hand side a student can see the most recent announcements and chat lines.
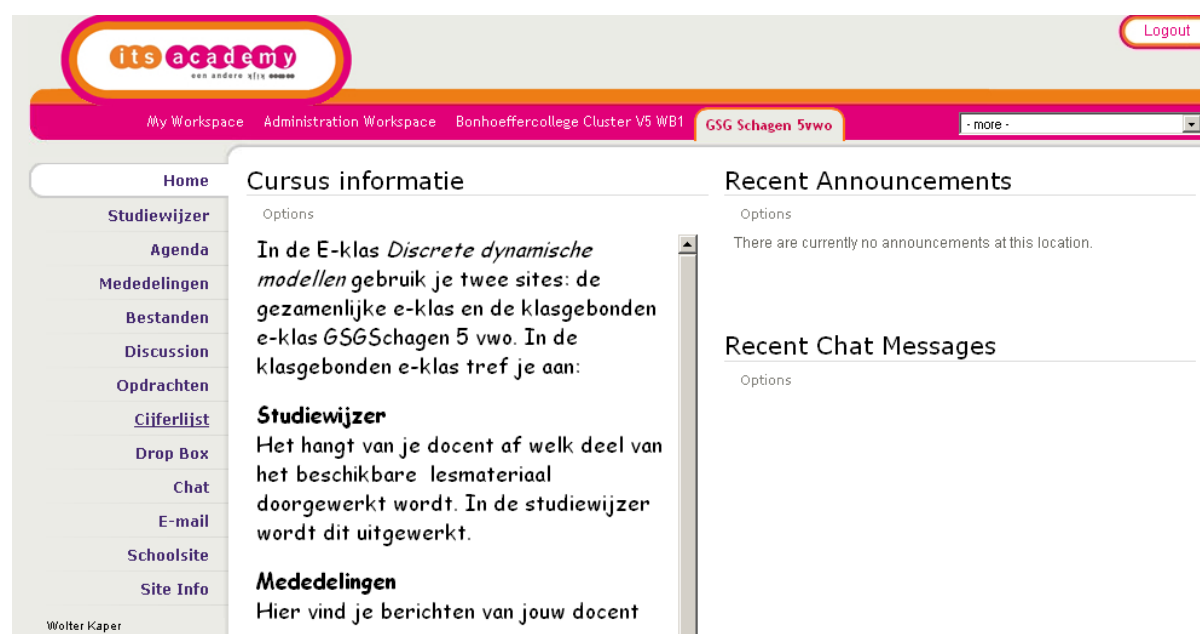

Figure 1: Opening screen of an e-class session

The study guide is very explicit about what the students are expected to do in a particular week and if there are assignments for which they should send in their answers. In the screen shot shown in Figure 2, a student is informed that (s)he is supposed to practice with Coach 6: the advice is to watch the screen cast on modelling inside the Coach environment the elimination of a medicine from the human body and hereafter try to make a computer exercise. Later on (s)he must watch the movie on predator-prey models and learn a bit more about computer modelling of such mathematical systems. The student is referred to exercise 81 of the textbook and the corresponding modelling activity file on the web. The translation of this exercise in Figure 3 shows that it is a rather standard mathematical exercise on population dynamics. Once the student has finished these preparatory tasks, (s)he can form or join a small group of peers and carry out part of the practical investigative task on clearance of drugs and alcohol from the human body. The teacher's strategy was not to make a study guide for the entire course in advance, but to prepare it only one week ahead so that he could anticipate the progress or study load of his students in the current week. This allowed him for example to create a screen cast related to difficulties that a large group of students actually had during the week, to give some additional explanations, and to prepare extra tasks. It is a form of just-in-time teaching. Besides, it is for the teacher one of the available communication channels to interact with his students, to motivate them, and show interest in their needs.

Home	⇄ **Studiewijzer**
Studiewijzer	Create/Edit 🗎
Agenda	
Mededelingen	**Studiewijzer week 4 juni**
Bestanden	
Discussion	Deze week een aantal oefeningen met coach.
Opdrachten	Bekijk de film "Afbraak van medicijnen" in de map met coach films en maak dan opdracht 4, een coach opdracht over de afbraak van medicijnen en alcohol.
Cijferlijst	Bekijk de film "Formules maken met Coach 6" in de map met Coach films en maak dan de opdrachten 5 en 6.
Drop Box	Bekijk de film over de prooi-roofdier modellen bekijken. Let erop dat een aantal zaken in deze film niet handig zijn. Bijvoorbeeld is vergeten om de tijdseenheid goed in te stellen en het aantal stroompijlen had
Chat	misschien ook wel minder gekund.
E-mail	Bij opdracht 7 moet je maken de coach opdracht 78. Deze opdracht staat in je boekje en in de map met coach opdrachten.
Schoolsite	Bij opdracht 8 moet je maken de coach opdracht 81. Deze opdracht staat in je boekje en in de map met coach opdrachten.
Site Info	Als dit klaar is moet je in staat zijn om een deel van de praktische opdracht over de afbraak van medicijnen en alcohol te maken in een groepje.
Wolter Kaper	Harm Houwing.

Figure 2: A sample page of the study guide

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81   In a closed wildlife park lives a population of foxes.
    This population of foxes is divided into three age classes, namely:

    Y = young animals   (0-5 years old)
    A = adult animals   (5-10 years old)
    O = old animals   (older than 10 years)

    The chance that a young animal matures equals 0.68.
    The chance that an adult animal gets old equals 0.30.
    The chance that an old animal 5 years later is still alive equals 0.20.
    Adult and old animals give birth to 90 fox cubs per 100 animals.
    In 2006 there were 2500 young, 1200 adult, and 500 old foxes in the park.

    a.   Convert the data into system of difference equations.
    b.   Plot the graphs of Y, A, and O in one diagram for the coming 50 years.

    Because the number of foxes decreases, it is decided to enlarge the number of breeding places so that the birth rate will increase.
    c.   Investigate how large the minimum birthrate must be so that the population of foxes in the park does not become extinct in the long run.

    When you set the step size in Coach6 equal to 0.2 you compute the annual population.
    d.   Plot in this case the graphs of Y, A, and O in one diagram.
    e.   Investigate what happens with the number of animals when you take a very small step size. What is in this model a realistic step size? Please explain your answer.

Figure 3: Fragment of the textbook with a Coach exercise on a population model

Another communication channel in the e-class is the chat room in which students help and motivate each other. At the beginning of the e-class it was made clear that this kind of collaboration was greatly appreciated and that idle chatting would not be tolerated. The main idea was that students working at home could overcome difficulties through discussions with their peers and the teacher in the chat room. The following snapshot of a chat session (translated and made anonymous) illustrates how such discussions went and were hardly off topic. At the same time it shows when students were (still) working in the e-class. In the session below, most of the talking was about using the Coach software. To understand what went on this chat session it is important to realize the students could always see on their screen who was present in the chat room and that they knew that they could be monitored. The teacher regularly participated in the discussion and often learned about the students' difficulties or their ease with the subject contents from the chat sessions.

T (17:50 CEST) hi *L*, do you get the third of a??
T (17:50 CEST) of the coach exercise..:P
L (18:28 CEST) No, havn't started with it yet sorry
L (18:28 CEST) I must first get that other
L (19:36 CEST) I always get "time not specified" ???
L (19:40 CEST) Has someone else this too?
L (19:42 CEST) *T* come to msnnnn!
J1 (20:01 CEST) Does anyone know how to do the Coach task (of skating) b
J1 (20:01 CEST) so, how to compute the final score?
L (20:04 CEST) That is where I am too... and I also do not get it
L (20:04 CEST) I placed behnd the outflow arrow a state box and at the outflow arrow 1.01*... but that does not work well :P
L (20:05 CEST) Oh no thatis another! The last of a thus that I do not get
J2 (20:11 CEST) I also do not get it at all *L*!
J2 (20:11 CEST) did you finish 10 and 14?
J1 (20:13 CEST) there you must add an inflowline 0.01.
J1 (20:16 CEST) because you miss that, say, thus you must do 0.01*speed (or whatever name you have used)
A (22:15 CEST) hey *H*

A (22:15 CEST) do you like the energy week
H (22:25 CEST) Hey *A*, that goes smoothly now:D
H (22:29 CEST) Did you really understand the coach task?
A (22:31 CEST) mwoah
A (22:31 CEST) it was not that easy
A (22:31 CEST) but my dad helped me a bit
H (22:32 CEST) Question: have you done b and c following the method of Houwing, ie letting something flow away, or so?
L (22:51 CEST) whaaa finally done :O
T (23:02 CEST) *L*...how should you do b of that coach task?
T (23:03 CEST) should you make a new model orso?
J2 (23:07 CEST) yeah
J2 (23:07 CEST) I am finally done
J2 (23:07 CEST) sweet dreams!!!!!!!

Figure 4: Fragment of a chat session between students in the evening

You may wonder about what kind of learning activities the students have been chatting. To give you an idea and to illustrate at the same time the use of screen casts, we show a predator-prey model that is implemented in the graphical modelling tool of Coach 6 and explained in a video clip. Of course, in written form, there is no way to demonstrate a movie, but the screen shot in Figure 5 shows a sample screen of the movie that is used to explain how to build and explore a simple predator-prey model through the graphical modelling tool of Coach, which is similar to the stock-flow approach of a system-dynamics-based modelling tool like STELLA. Students can watch the movie (also through a simple movie player that works on any PC) or go step-by-step through it while trying to make a similar exercise. The movie could also be used as a digital answer to the exercise made available to the students in the e-class after they have worked on the problem themselves.
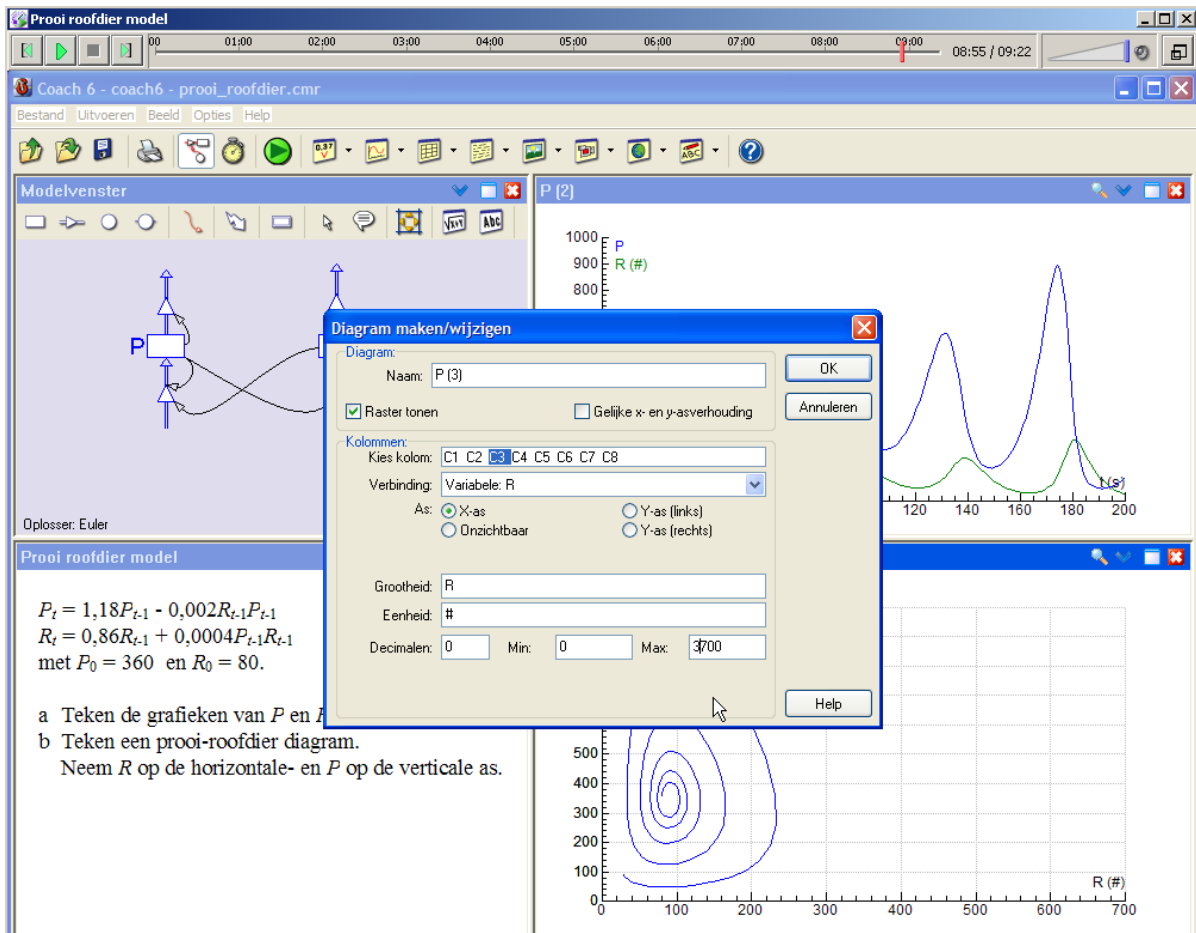
Figure 5: Sample screen from a movie delivered thought the e-class and explaining Coach in the context of a mathematical model of a predator-prey system

3. Screen casting in the e-class

Besides the chat facility, which effectively supported the communication in the e-class, screen casting was the killer application appreciated by all students. This asks for a description of how the screen casts, i.e., the video clips containing a computer instruction captured for the teacher's screen and a voice recording of the explanation that the teacher gives, were created and applied in the e-class. The success of our form of screen casting can be underpinned by research-based principles of multimedia learning.

For the creation of an instruction movie one needs the following equipment: a personal computer, standard headphones, a microphone, and screen capture software. The choice of the microphone and the recording software is most crucial for the quality of the created movie. One needs a high-quality microphone with enough noise reduction: we used the Samson C01U USB condenser micro-phone, www.samsontech.com, because it matches this criterion and is not too expensive. The choice of the screen capture software is large: Adobe Captivate, BB Flashback, Camtasia Studio, and so on. Ease of use and the quality (sound and image), format, and file size of the created movies are important issues. We are happy with BB Flashback, www.bbsoftware.co.uk, in the sense that it is simple to use, not expensive, and creates small Flash movies of DVD quality. To give you an idea: a recording of a session that lasts 5 minutes leads to a Flash movie with a file size of about 1MB (depending on the compression used), which means that it can be quickly downloaded from the VLE to the computer of the student or teacher at home.

The aims of screen casting are simple: to allow students to

- see and hear the thinking and explanation of a teacher when doing a task;

- watch whenever and as many times they want;

- go step by step through an instruction;

- look at the whole process and not only at the final result of an activity.

The main benefits of the screen casts in the e-class are that they support student learning outside the classroom, function in case of software instruction better than user manuals or help pages, and help the teacher in the sense that (s)he can make optimal use of the face-to-face contact time with students. As Garner (2008) suggested, use of screen casts for feedback to student assignments and for answering student questions in areas of conceptual difficulty is also a strong option for learning support, the value of which should not be underestimated.

Teachers often think that it is difficult and time-consuming to make good screen casts, but as Fahlberg et al (2007) already pointed out this is not true. It is in fact more a matter of getting classroom experience in teaching with a computer, mouse, and possibly tablet technology than of getting familiar with technology. In addition, it can be from pedagogic point of view wise not to make movies of perfect software use, but to show students the real use of computer programs (with sometimes some idiosyncratic actions of users). In this way, the standards of tool use are not set immediately too high for students, they do not get the impression from clean and elegant teachers' solutions that they themselves should be able in a straightforward fashion to work in a similar sophisticated manner, and there is space left for them to recommend improvements. One should also keep in mind that the movies have an instructional purpose and therefore must be professional, but not perfect, and that they must capture the actual process as naturally and authentically as possible (no artificial planning/scripting).

When it comes to movies in which mathematics or science concepts and methods are explained, then of course the standards of the content must be kept high. But also in such cases, once a teacher notices that students have some difficulty, say with a calculation, (s)he can quickly generate a screen cast to demonstrate a task or give an explanation, and then give another exercise to try. This concept of ICT support of learning has been applied consistently in the new 'Getal & Ruimte' textbook series: screen casts of mathematical exercises, which are supposed to be made with the help of software such as GeoGebra (www.geogebra.org), Coach, or Java applets for learning and practicing school

algebra (Heck *et al*, 2007), have been created and the students can use them to learn and practice mathematics. Figure 6 exemplifies this idea: on the left-hand size a screen cast with explanation of how to solve stepwise an equation containing roots, and on the right-hand side a screen shot of an environment in which student can practice at various levels. It is our experience (see also Heck et al 2007) and of others (e.g., Bennedsen and Caspersen 2005; Fahlberg-Stojanovska and Stojanovska 2007) that screen-cast-based exercises encourage students and provide them the necessary scaffolds to carry out mathematical tasks and to practice skills.
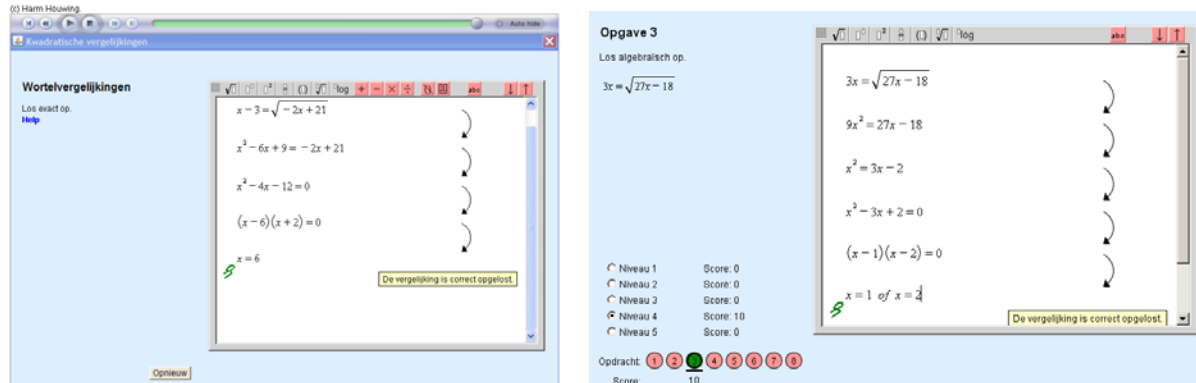

Figure 6: A screen cast (left) on solving equations and a screen shot (right) of an exercise

Cognitive theories of multimedia learning (for a collection of papers see Mayer 2005) provide in our opinion a theoretical underpinning of the success of the screen casting in the e-class. Let us first linger upon the instructional design principles (cf. Mayer 2002; Sweller 2003) with regard to screen casts explaining the use of Coach, GeoGebra, the homework delivery system of the VLE, and so on. In comparison with written user manuals, screen casts as demonstration or tutorials of software packages reduce cognitive load because of the

- *multimedia effect:* a combination of verbal and pictorial material usually helps learners.

- *modality principle:* textual information is preferably presented in spoken language. Appropriate use of voice narration is consistent with Paivio's (1986) dual coding theory.

- *split-attention effect* (aka 'spatial contiguity and temporal contiguity principle'): Ciernak et al (2009) explain against the background of cognitive load theory why people learn better when words and pictures are physically and temporally integrated. In accordance with this, it is a clear advance when a student can listen to an explanation of tool use while watching at the same time what is going on at the computer screen, and does not need to split visual attention between viewing the computer screen and reading a tutorial.

- *personalisation, voice, and image principles:* people learn better when words of a multimedia presentation are in conversational style rather than formal textbook style and when the words are spoken in a standard-accented human voice; but people do not necessarily learn better when the speaker's image is on the screen (this may distract students). A screen cast does not need to be streamlined: it is beneficial if students see in a screen cast an example of real tool use, including mistakes that are later corrected, searches in the menus for an appropriate item, user's hesitations, and so on. This could be referred to as the tool-use fidelity of the screen casts, i.e., the alignment between the tool-use shown in the video clip and the way people work use the tools in real, practical work.

- *self-regulation principle:* video support works better when learners can replay fragments of the video clips as many timed as needed, that they can halt the video clip in order to think or try things out, and have full control over the items to look at in the screen casts.

- *redundancy and coherence principle:* people learn better when irrelevant or redundant information is not presented. 'Less is more' is a good slogan for screen cast design.

- *worked-out example effect:* learning from worked-out examples is effective for initial skill acquisition. This principle is robust (Schwonke et al 2009) and works well in a first learning phase, when focus is more on gaining understanding than on meeting performance demands. Students typically prefer this style of learning, but it can become detrimental when learners are already

more experienced and know how to perform the task (the so-called *expertise-reversal effect*, Kalyuga et al 2003).

The above principles are also applicable for the design of screen casts that deal with content, say mathematical tasks such as problem solving and algebraic manipulation. In a worked-out example one can pay attention to the problem formulation, chosen strategies, intermediate solution steps, checking of solutions, and so on. Hilbert et al (2008) give in this case the advice to gradually fade the support provided as learners make progress and acquire more knowledge and skills, and to include self-explanation prompts (like question 81e shown in Figure 3) in order to help students become self-reliant, competent, and self-confident. One can also improve learning with multimedia by paying attention to common mistakes and alternative conceptions (Muller et al 2008).

4. Experiences with the e-class in the pilot project

How did the students experience the e-class? Our data come from

- evaluation reports of the students;

- interviews with students;

- a questionnaire at the end of the study year: 175 students responded from 3 schools; 88 male and 87 female students at pre-university level; 53 students were in the Nature & Technology stream.

The data obtained from the questionnaire are summarized in table 3.

Analysing the results of the questionnaire, the interviews with students, and the students' evaluation reports, we conclude that most of the students appreciated that they could

- work with and learn from screen casts;

- consult their peers and the teacher in the chat room;

- plan more or less their working hours;

- learn a lot, in a mixed and attractive approach;

- build and simulate graphical models of Coach 6; they liked the software once they got more familiar with it through the screen casts and by helping each other.

Table 3; Summary of the results of the student questionnaires

\ scale property \	much lower (%)	lower (%)	normal (%)	higher (%)	much higher (%)
difficulty level	0	1	24	48	27
amount of homework	0	2	19	27	52
quality of lesson material	4	12	63	15	6
ability to study independently	3	24	43	17	13
usefulness of the course	12	13	49	18	8
clarity of explanations	12	33	42	8	5
variety between texts and task	3	7	70	15	5
perceived teacher's enthusiasm	20	12	48	7	12
preparedness for university study	16	21	51	9	2

Many students who were sure that they would choose a higher education study in technology or exact sciences thought that the e-class prepared them better for their future study than traditional lessons. The following fragment of a student report illustrates these conclusions:

"The e-class is really of our time and because it is based on the idea of 'blackboard' it will be useful later at the university; then you already know how such system works. I think that the e-class can go far because the explanation that you get through the videos is sort of individual guidance, which works of course better than explanation to the whole class. The instructions had been recorded very clearly and in case you did not get the idea yet, you could rewind the movie; I found this a great advantage.

> *On the other hand, I found that the e-class was sometimes difficult; in particular at the beginning it was not very clear how the program was set up. Especially at the beginning I ask my dad for help because I found the Coach 6 exercises at a tougher level than we were used to. Also I spend whole evenings working on the tasks, whereas I usually do less mathematics at home."*

A positive interpretation of the last paragraph is that this student found the course challenging. In fact the student was right saying that the course was more demanding and took more time than usual. About one quarter of the students found the course too difficult, and about half of the students found it difficult, but manageable. About half of the students brought up that they had much more homework than usual. Some students reported that they worked weekly on the entire Sunday afternoon and evening to meet the deadlines for the online assignments. Many students characterized the final computer assignment as difficult, although the result less mathematical competencies below average complained more about the difficulty level and the amount of homework, perhaps because the weekly assignments painfully revealed their difficulties and weaknesses. At the same time this is important information for the teacher to make use of in the preparation of his/her lessons.

The teachers in the design team had actually been too optimistic about the amount of work for the students. But honestly, it must be taken into account that the course was not given exclusively to the prospective Mathematics D students. There was in the pilot project a strong correlation between the mathematical skills level of the students and their appreciation of the e-class (more able students liked the e-class more). We expect that students who are not so good in mathematics will not choose Mathematics D as optional subject. Experiences in the last and current study year with students who have chosen this subject indicate that the level and amount of work in the e-class was in fact not as bad as it looked initially.

But students were not the only ones who had been busy in the e-class of the pilot project: the same holds for the participating teachers. Especially, the weekly grading of homework handed in by the students was time-consuming and stressful. On the other hand, monitoring of work progress was also a stimulus for the students to do their homework: postponing behaviour was penalized. Also, teachers had to regularly log into the VLE to check if everything was going well and if their students needed a helping hand. Teachers received more emails than usual from their students that needed to be answered. On the one hand this is a positive sign that the communication between students and teachers in the e-class was functioning well, but on the other hand the complaints of the teachers about the workload in the e-class must be taken serious: a teaching assistant, perhaps a bachelor student from a university, seems to be a solution. What is interesting to note is that almost all teachers, regardless of the work it took, looked back at the pilot project as a successful enterprise, with great prospects. The majority of the participating teachers continued to run an e-class in the following years, sometimes in a less labour-intensive setting. A quotation:

> *"A selling point of the e-class is in my opinion that the student can be busy with the subject matter in different ways. It is extremely varied, with individual and group work, instruction movies, project work, and so forth. Besides, working with a VLE and a computer working environment like Coach are good preparatory activities for continuing education at university or higher vocational level, where this way of teaching and learning is commonplace."*

5. Future directions

In the e-class of the pilot project we had not encountered one of the main disadvantages of online learning that is often brought up, namely, the lack of social contact. The main reason lay in our opinion in the blended approach: face-to-face teaching and learning at school was combined with web-supported instruction outside the classroom and at home. This seemed to work well. It also matches the so-called study house concept, in which students are held more self-responsible for their learning, and it even seems to work better than traditional instruction in the classroom because students can work in the e-class in an individual way that suits their learning style best.

The success of the pilot project has resulted in a large project for the academy, within the framework of the Nationwide Programme for e-Learning (www.surffoundation.nl) for the years 2008-2010, in which sixteen e-classes are designed and implemented in clusters of schools in the region of Amsterdam, in a joint effort of about forty teachers of secondary schools and higher education

institutes. All developed e-classes will be field tested in several schools, thoroughly evaluated, improved, and preferably certified by the countrywide Programme Renewal Committees in mathematics and science education. This time the modules will not be restricted to Mathematics D, but there will also be modules for the subjects Informatics and Nature, Life, and Technology. Other aims of the project, besides development and implementation of e-classes, are:

- improvement of the transfer from secondary to higher education concerning content of subject matter;

- raising of the quality of mathematics, science, and technology teaching and learning at secondary schools by teacher professional development;

- increase in the number of teachers in exact sciences and technology;

- realisation of sustained contacts between teachers of secondary and higher education;

- increase in the number of students who choose a follow-up study in exact sciences and technology.

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