Studies on the design of free text communication and video components in Computer Assisted Learning

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Doctoral Thesis

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Abbreviations:

The following abbreviations are used in this thesis:

CAL	Computer Assisted Learning	*FTC*	Free Text Communication
VAS	Visual Analogue Scale	*VI*	Video Instruction
C	Control group	*VTS*	Video Training System
E	Experimental group	*IT*	Information Technology

Preface

This thesis is based on the following published/accepted studies:

I. Martin Schittek, Nikos Mattheos, Hal C. Lyon, Rolf Attström. **Computer assisted learning. A Review**. European Journal of Dental Education 2001; 5(3): 93-100.

II.* Martin Schittek Janda, Anders Nattestad, Nikolaos Mattheos, Daniel Nebel, Anders Wagner, Rolf Attström. **Simulation of patient encounters using a virtual patient in periodontology instruction of dental students: design usability and learning effect in history-taking skills.** European Journal of Dental Education 2004; 8(3): 111-9.

III. Martin Schittek Janda, Antonella Tani Botticelli, Nikolaos Mattheos, Daniel Nebel, Anders Wagner, Anders Nattestad and Rolf Attström. **Internet mediated instructional video. A randomised controlled trial comparing a sequential and a segmented instructional video in surgical hand wash**. European Journal of Dental Education, in press 2005.

IV. Antonella Tani Botticelli, Martin Schittek Janda, Daniele Botticelli, Nikolaos Mattheos, Rolf Attström. **The effectiveness of a video support in the teaching of manual skills related to initial periodontal therapy tested on phantoms**. International Journal of Computerised Dentistry, in press 2005.

* Paper II is composed of two individual research studies, which were originally accepted as two separate articles. However, due to the journal's need to save space, the editor requested that the two studies be merged into one publication (see appendix). In this thesis, the two articles are reported separately as study IIa and study IIb.

Abstract

The research conducted so far in computer assisted learning (CAL) can be categorised in three different levels: the basic level, the component level, and the course or holistic level. Because research in CAL in health education has been driven by enthusiastic teachers, it is well understood that most studies are built around existing structured courses and focus on holistic evaluation of the learning process. There seems to be a lack of original research on the actual role of CAL components in the learning process. The aim of this thesis was to contribute to our understanding of the component level in order to be able to develop better instruments for teaching. This thesis focuses on two different components, video and free text communication (FTC). Four studies were conducted:

1) A systematic literature review to investigate the state of the art within CAL in dental and medical education.
2) A design and usability test as well as one randomised, controlled trial to investigate the effects of training with FTC on the development of skills in history taking.
3) A randomised, controlled trial to test the learning effect of a segmented vs a whole video.
4) A randomised, controlled trial to test the learning effect of segmented video vs live demonstration through a camera.

Most of the studies covered in the literature review were conducted at the holistic level and therefore unable to identify the importance of individual CAL functions in the learning process. The students' ability to take a history of real patients improved significantly after one training session with FTC. The learning outcome of segmented videos appears to be better than that of whole videos, and segmented videos are watched more by the students. The results of the experimental studies indicate that both FTC and video can play significant roles in the CAL process. Research-based development of CAL components would increase the potential of CAL in education.

Populärvetenskaplig sammanfattning

Den forskning i datorstött lärande (DSL) som hittills har gjorts, kan kategoriseras i tre olika nivåer:

- den grundläggande nivån (t.ex. betydelsen av fonter, fontstorlek och färg),
- komponentnivån (t.ex. betydelsen av olika typer av feedback)
- kurs- eller holistiska nivån (där man studerar helheten i lärandesituationen i t.ex. virtuella klassrum och Internetbaserade kurser).

Eftersom mycket av forskningen i DSL inom medicinsk och odontologisk utbildning har genomförts av entusiastiska lärare, är det förståeligt att majoriteten av studierna utgår från existerande och strukturerade kurser samt att de fokuserar på den holistiska utvärderingen av lärandeprocessen. Det verkar saknas forskning på den egentliga rollen som de olika komponenterna i DSL har i lärandeprocessen.

Avhandlingens mål är att bidra till förståelsen av komponentnivån så att bättre komponenter kan utvecklas för undervisning. Avhandlingen fokuserar på två olika komponenter; nämligen video och fritextkommunikation (FTK).

Fyra studier genomfördes:

1) En systematisk litteraturgenomgång i syfte att undersöka och sammanställa det senaste inom DSL i odontologisk och medicinsk utbildning.
2) Effekten av att använda FTK på anamnesupptagning hos tandläkarstudenter med sin första patient.
3) Skillnaden i inlärning vid visning av en uppdelad och en hel instruktionsvideo.
4) Skillnaden i inlärning vid visning av en uppdelad instruktionsfilm och en realtidsinstruktion genom en kamera.

Litteraturgenomgången visade att nästan alla studier som genomförts är gjorda på den holistiska nivån och att det därför inte går att identifiera vilka enskilda funktioner inom DSL som är viktiga för inlärningsprocessen. Studenternas förmåga att ta upp anamnes på riktiga patienter ökade signifikant efter ett övningstillfälle med FTK. Segmenterad film verkar ge en bättre effekt på inlärning och studenterna ser på den längre. Resultaten av de experimentella studierna indikerar att både FTK och video kan spela en signifikant roll i inlärningsprocessen med DSL. Forskningsbaserad utveckling av komponenterna i DSL skulle öka potentialen av DSL i utbildningen.

Introduction

Computer Assisted Learning (CAL) applications have been shown to enhance learning outcomes on many occasions (Schittek, Mattheos et al. 2001). These outcomes might include not only better comprehension, better understanding, and better retention of knowledge but also easier and better acquisition of psychomotor and sometimes cognitive skills. It is therefore well documented that, in specific applications, computers can significantly enhance the learning process (Tsai, Tsai et al. 2004). However, this is not always the case. Several, more recent studies on CAL have reported a compromised learning outcome, inferior results, and even frustration among students and staff (Williams, Aubin et al. 2001; Maag 2004). Therefore, having overcome the "hype" of the early 1990s, CAL has reached the stage where research is urgently needed to identify factors of success, define best practices, and guide future development (Schittek Janda 2003).

Indeed, research on CAL has been conducted from its inception in an effort to identify which technology-related factors contribute to the success or jeopardise the implementation of computers in the learning process. The research conducted so far can be analysed at three different levels:

- The basic level
- The component level
- The course or holistic level

(see table 1).

Level	Description	Explanation	Examples of research
Basic	Different forms of presentation of information to the learner	How the presentation of information affects the learner (Cognitive science)	▪ Text (fonts, size, colour….) ▪ Layout (menus, screen size, tables…) ▪ Images (colour, clipart, size…) ▪ Videos (resolution, size, duration…) ▪ Sounds (incorporated, duration…) ▪ Animations (duration, size…)
Component	Tools to process information	How the information should best be used to improve the effectiveness of learning (Combination of cognitive and pedagogical sciences)	▪ Interactive use (quizzes, importance of feedback) ▪ Free text vs. predetermined options ▪ Force feedback ▪ Navigation ▪ Video (segmented/continuous)
Course/ Holistic	Combination of different tools	The whole package, how to put together all the components that will make up the learning experience (Pedagogical science)	▪ Computer assisted learning software ▪ Internet-based learning ▪ Virtual classrooms

Table 1. Research levels in computer-based learning.

Research levels

The Basic Level

At this level, research focuses on the actual content or how the raw information is made available through the computer application. Research on this level often deals with the connection between different types of sensory stimuli, input of information, and learning.

This type of research could investigate the optimal size and form of fonts for the comprehension of text; optimal screen size; and optimal resolution for better perception of form, shape, and colours. The importance of text, images, and sound for activating memory circuits and mechanisms of short- and long-term memory, for instance, are other targets of research at this level (Dalal, Quible et al. 2000; van Schail and Ling 2003).

Basic level research relies greatly on developments in cognitive science as well as in the biomedical sciences. Growing interest in different fields of design (industrial design, web design, interaction design and so on (Schenkam and Jönsson 2000; Diaper and Waeland 2000)), has enabled research at the basic level of computer applications to make significant progress in the last

decade. However, it appears that developers of educational software in the medical sciences have been slow in implementing these findings.

The Component Level

At this next level, research is focused on investigating how the same content or basic information could be delivered through different methods or applications (Schittek, Botticelli et al. 2005). Information technology provides a seemingly unlimited variety of options to facilitate the learning process, each of these options constituting a different "component". For example, a piece of text can be delivered via a complete text file or an interactive web page where the reader's pathway through the text is guided through a specific interface (Maag 2004). An asynchronous discussion can take place through a web board, an e-mail list, a collaborative document, or an open document with consecutive authors. Text-based communication can be conducted through free text or similar content-predetermined options.

Research at this level is important as we gradually move towards more flexible models of "blended" learning. The latest developments indicate that, in the near future, educational structures will increasingly rely on a "hybrid" model, where CAL modules or components will merge with more traditional ones in the development of individualised learning environments.

The Holistic Level

At this highest level, research has targeted various aspects of the learning experience that occur after the completion of structured CAL courses. This is probably the level on which the majority of CAL research has been focused in the last decades (Janda Schittek 2003). In many studies, information technology (IT) has been applied to a variety of educational scenarios and courses. Parameters evaluated after completion of a course have typically included students' acceptance and satisfaction, staff opinions, test scores and results, drop-out rates, students' motivation indicators, time per task, and cost-effectiveness measurements (Schittek, Mattheos et al. 2001).

Research at a holistic level can contribute much to our understanding of specific educational methodologies and pedagogical strategies. However, the potential of even the best designed studies at this level to identify important factors in the actual use of IT is limited. Many important variables are involved in these studies (types of students, teachers, methodologies, equipment, culture, socio-economic factors, and so on), which cannot be isolated or controlled and which limit the reproducibility of the results in other environments, even when identical technology is used. The actual effects of IT are therefore diluted by the presence of overall methodological factors.

Main approach

Since research on CAL in health education has been driven by enthusiastic teachers of healthcare, it is well understood that most studies are built around existing structured courses and focus on holistic evaluation of the learning process, where CAL is only one of the important variables. Therefore, despite large investments and a substantial body of research, the contribution of IT components to the learning process remains largely unclear and is diluted by many confounding factors.

At the opposite end, research conducted at the basic level appears to be voluminous as well. The problem at this level is that research has seldom been clearly related to educational settings and has not attracted the attention of educators and course designers. Rather than more results at the level of basic research, an interdisciplinary dissemination of existing results is urgently needed. This would allow educators to better comprehend these results in the scope of the learning process and implement them in educational practices.

There does, however, appear to be a lack of original research at the second level, the influence of the CAL “components”. Few studies so far have attempted to identify individual “components” or “elements” and consequently evaluate them isolated from whole learning structures and courses. The reasons for that might be many, but one overriding reason is that studies not involving a whole educational model have been traditionally

considered of inferior utility in educational research circles. The latest trends of flexible, blended, and modularised learning, however, indicate the urgent necessity of such data. If we are to better understand the potential and limitations of IT, more research that isolates the CAL components from other complicating educational structures is needed.

For this reason, this thesis attempts to contribute to the component level and add more knowledge so that better instruments for teaching can be developed. The thesis will focus on two different components, video and free text communication (FTC).

Components

Video

Video has been a powerful educational tool for decades (Goldman 1973; Toussaint 1971). Yet, there are those who claim that we need more research on video to fully understand the power of the media (Shephard 2003). The value of video in learning has been appreciated, and instructions on how to best produce instructional videos have been available for a long time (Brusch 1975).

Earlier, it was hard to produce a video film because advanced and expensive cutting equipment for editing was needed. Today, the cutting table has moved into the computer, and the equipment for semi-professional video production is affordable for university faculties and relatively easy to use. Courses for university instructors on how to produce learning material are available today. These films are usually designed to be shown on TV screens.

Lately, films to be shown on the Internet or incorporated in CAL software are also being produced. The quality of these films is uneven, and they can be shown with different technical solutions. There are still some technical drawbacks, however, to delivering long video sequences without any interruption or disturbances. The server log files of sites where both sequential and fragmented instructional videos are

available indicate that users prefer the shorter video clips to the longer videos when both are available (http://www.odont.ku.dk/tmk/digital video1.htm). Users' preference for short videos combined with the need to deliver educational material over the Internet has made it imperative to test the effect of short videos on learning and retrieval of knowledge by dental students. A part of this thesis therefore investigates the learning effectiveness of fragmented videos versus the complete sequential video and analyses the attitudes of the user towards video as a learning aid. Further, the effectiveness of computer-based video support in the training of manual skills related to periodontal treatment was studied.

Free text communication

Modern teaching methods have been designed to prepare students with the necessary skills prior to patient contact for advanced procedures (Chang, Chung et al. 2002). Simulations have become an important educational tool in the development of healthcare competence (Gilbart, Hutchison et al. 2000). Virtual patients have been used to train medical and dental students in numerous institutions. "Talking" simulators are rare because of the time and effort it takes to program the computer to understand user-driven communication. Some designers have solved this problem by providing the student with a long list of possible questions to ask the "virtual" patient. This limits the user's choices, and it is easy to get around the system. With a list of questions, it is possible to passively activate memory by searching the provided options for recognition. If users could write questions in a free text mode, students would probably search their memory more actively and thereby activate and retain knowledge better. Such FTC would also be much closer to a realistic scenario of communicating with the patient, for which the student is training. Thus, one of the studies in this thesis deals with FTC.

Aims

To:

- Summarise current experience in the field of CAL applications in health education.
- Evaluate the effects of training with FTC on dental students' ability to take patients' histories.
- Investigate the learning effectiveness of fragmented videos versus the complete sequential video and analyse the attitudes of the user towards video as a learning aid.
- Investigate the effectiveness of computer-based video support in the training of manual skills used in periodontal treatment.

Materials and methods

Study I (Literature review)

The literature review aimed to summarise past experience, the current state of the art, and future trends and tendencies in the field of CAL in health education. The review focused on undergraduate and postgraduate education of primarily dental but also medical professionals.

Studies up to the year 2000 were examined and categorised. Most of the publications selected for inclusion in the review originated in the 1990s and focused on:

- The educational value of CAL.
- The effectiveness of CAL in comparison to traditional teaching.
- Attitudes towards CAL among students, staff, and professionals.
- Visible future trends and developments.

Updated review

A second systematic search of the published literature was made in 2004. A MESH search on MEDLINE with the MESH term "Computer Assisted Instruction" and restricted to "Major Topic headings only" was used. The articles selected for inclusion had to meet the following inclusion criteria:

- The trial was randomised and controlled.
- The trial compared CAL with another method of instruction.
- The studies on students were studies on groups of academically homogeneous dental or medical students.
- The trial was published between January 2000 and July 2004.

Study IIa (Design and usability test)

The first part of the second study aimed to develop a simple virtual patient with the main principle of enabling communication between the student and the virtual patient in free text, without any pre-determined options or pathways.

The application developed recognises a number of trigger words or parts of words, which in combination indicate a question. The application searches a database for a relevant answer and delivers this as text, sound, image, or movie to the student (Fig. 1).

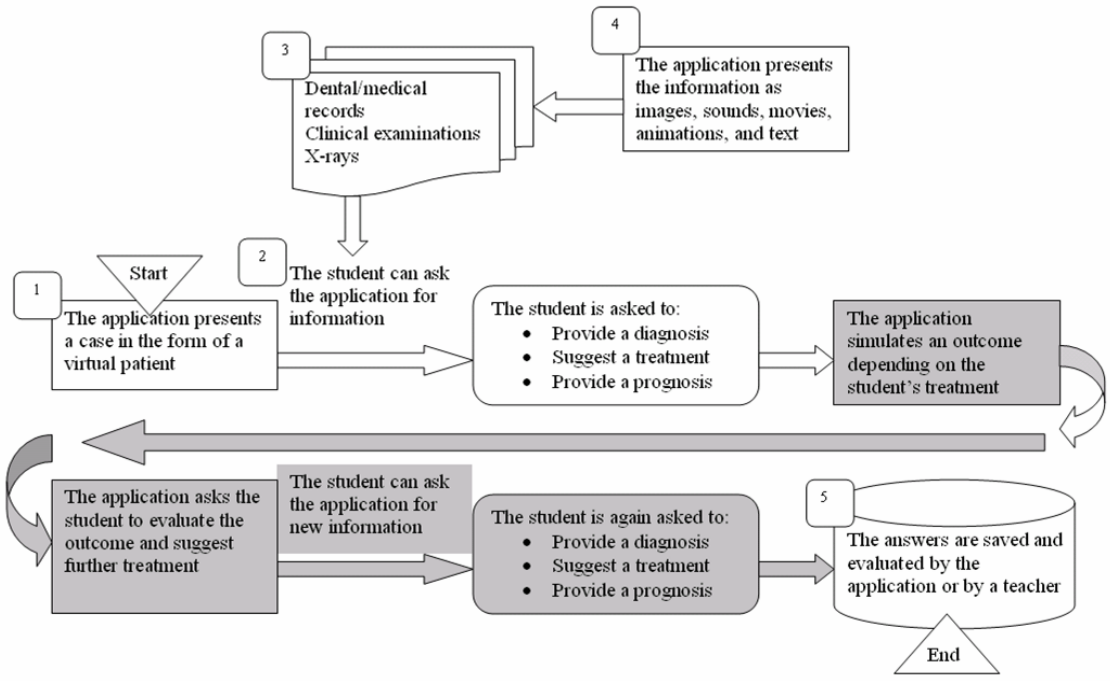

Fig 1. Flow chart illustrating the components of the virtual patient. The dark-coloured fields are functions still under construction while the white boxes contain functions that are programmed and described in the present report. The usability test relates to boxes 1–5.

The rules listed below must be observed by users of the application:

- Work through the whole case.
- Ask only one question at a time.
- Do not ask questions that allude to prior question content.
- Rephrase the question if the virtual patient does not understand the question, and move on if the application cannot provide an answer after three attempts.

The virtual patient is designed to reflect a real scenario as much as possible to put the student in the role of a professional. To begin with, the application presents a case to the student, who is asked to collect essential information (history, status, X-rays, and so on) and on the basis of this information provide a diagnosis, suggest a treatment, and indicate a prognosis. (Schittek, Mattheos et al. 2001)

The application is divided into the following sections:

1) History taking
2) Clinical examination
3) X-rays
4) Diagnosis
5) Treatment planning
6) Prognosis
7) Log and feedback of the usage as well as evaluation.

The student can move freely between the first six sections.
An example of the "status" screen is shown in Fig. 2.

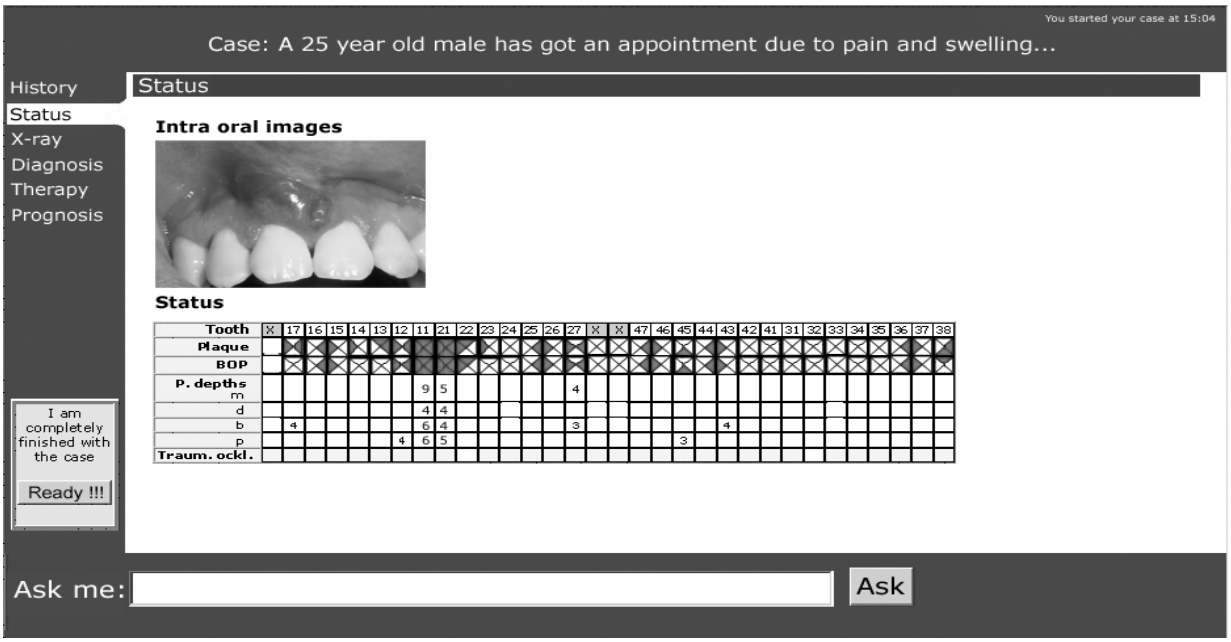

Fig 2. Screenshot of the interface with the virtual patient where the student communicates in free text with the application. The figure illustrates the presentation of clinical data by the application.

Usability test

A simple usability test of the virtual patient was undertaken by seven third semester dental students. The students volunteered to test one case with the virtual patient. The students were isolated in separate cubicles during training. The computer logged each entrance and recorded the time. The students were instructed to use the software and only take a patient history.

Study IIb (Virtual learning)

The second part of the second study aimed to test FTC principles between the student and the virtual patient, without any pre-determined options or pathways.

The material

All 50 students in their second semester at the Centre for Oral Health Sciences, Malmö University, Malmö, Sweden, participated in the study. Of these, 11 were excluded for the following reasons:

- nine patients did not show up
- two patients refused to be videotaped

The remaining 39 students met their very first patient in the middle of their second semester and participated in the study.

The students were randomly assigned to two groups. Both groups underwent standard instruction in professional behaviour and history taking of patients. The instruction comprised two 1-hour lectures on history taking in small groups (7–10 students). The experimental group (G1) then worked with the virtual patient 1 week prior to their first patient contact, while the control group (G2) was first allowed to use the virtual patient after their first patient contact. The study was disclosed to the students after it was finished. All students, therefore, were allowed to work with the virtual patient, and this was a requirement for passing the course. The control group was first allowed to work with the virtual patient before their second patient encounter (see Fig. 3).

Prior to the use of the virtual patient, the students were given specific instructions on how to work with it. The students had to go through one case each. Each student had his or her own cubical during training. The computer logged each entrance and recorded the time.

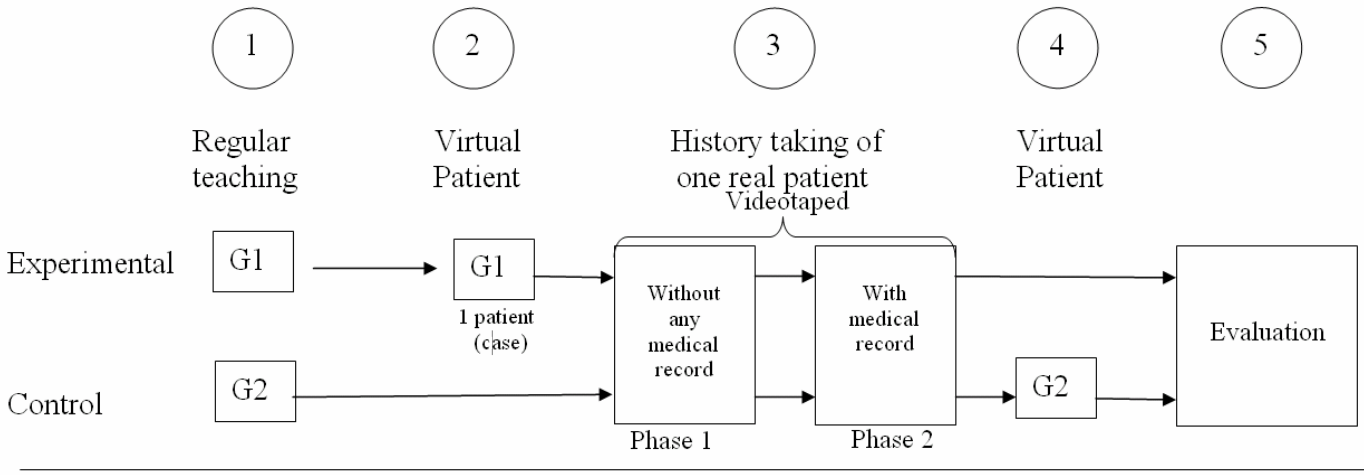

Fig 3. Illustration of the design of the study with the experimental group (G1) and the control group (G2). Note that the study was divided into five parts and that during part three, the students and patients were videotaped during the entire process of history taking.

Encounter with the very first real patient

The encounter with a real patient was divided into three phases, of which the first two were video recorded for both groups of students:

- Phase 1, Initial questioning of the patient: Both groups were instructed not to use any instructional notes or records during questioning.
- Phase 2, Continued questioning of the patient: When the students felt they had finished interviewing the patient, they were allowed to consult the medical record and continue their questioning of the patient.
- Phase 3, Clinical examination: When the students considered themselves ready, the video recorder was stopped and they began their clinical examination of the patient. (Phase 3 was not evaluated in this study.)

The patients were instructed not to reveal any information but only to answer the questions as asked by the student.

Fig 4. Screenshot from one of the recorded videos.

Parameters of analysis

Use of time

The total amount of time the students needed to complete their medical-dental history session was recorded. The total time (T) was then divided into two subgroups:

- (T1): time used before the student chooses to consult the medical journals or notes (phase 1).
- (T2): time used while consulting the printed form (phase 2).

Analysis of questions asked

All questions asked by the students were compared between the two student groups. The questions asked during phases 1 and 2 were recorded separately.

The videos were analysed, and the questions were divided into three categories:

- Qcr (Critical Questions): Questions, which four senior teachers had decided beforehand, were questions that were critical to ask when meeting a patient for the first time (16 questions).
- Qte (Total Questions excluding follow-up questions): These questions contribute important knowledge to the given case.
- Qti (Total Questions): All questions, including follow-up questions.

Professional behaviour

One experienced clinician involved in dental education was asked to blindly evaluate the videos of the students taking the medical-dental history. The teacher had previously taught the students but was not associated with the study. The students' performance was rated on a scale from 1 to 6 (poor–excellent) based on the following criteria:

- Language precision
- Order of questions (logical sequence)
- Empathy

Study III (Segmented video vs. whole)

The third study aimed to investigate the learning effectiveness of fragmented videos versus the complete sequential video and to analyse the attitudes of the user towards video as a learning aid.

Video on the Internet

An instructional video on surgical hand-washing was produced according to the faculty's hygiene and cross-infection control standards for surgical hand-washing. The video was available in two different forms on two separate web pages: one as a sequential video and one fragmented into eight short clips. The video was in total 6'11" long.

Experimental group

The first web page presented the content divided into eight parts. The eight different parts were organised as eight images. Clicking on an image would play the respective part of the video. Each part of the video was accompanied by a short description (see Fig. 5). The server could log the total time the student spent watching the video, as well as the time spent on each of the eight parts and the order or sequence of switching between the different clips.

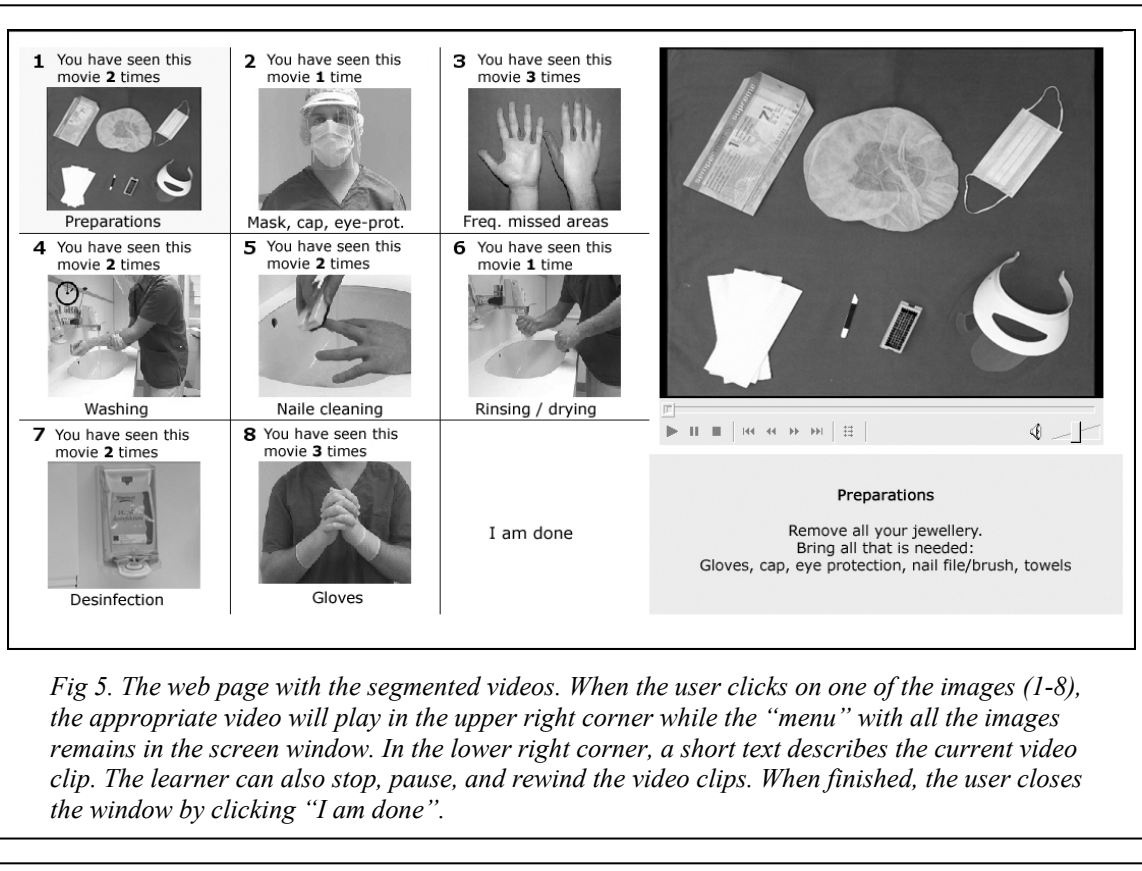

Fig 5. The web page with the segmented videos. When the user clicks on one of the images (1-8), the appropriate video will play in the upper right corner while the "menu" with all the images remains in the screen window. In the lower right corner, a short text describes the current video clip. The learner can also stop, pause, and rewind the video clips. When finished, the user closes the window by clicking "I am done".

Control group

The second web page hosted the sequential video with exactly the same content as the experimental group. It allowed the students to watch the video at almost full screen size without interruptions. A navigation bar provided the options to stop, start, pause, and wind the video, similar to traditional VCR players (see Fig. 6). No other information existed on the web page. The server logged the time each student used to watch the video.

Figure 6. The web page with the whole video and the navigation bar. The student can play, stop, pause, and rewind the video. When finished, the user closes the window by clicking "I am done".

The material

A cohort of second semester dental students (n=40) at the Centre for Oral Health Sciences, Malmö University, Malmö, Sweden, was invited to participate in the study. Participation was voluntary, but students who wanted to assist during periodontal surgery were advised to participate. This was the only chance they had to acquire and demonstrate competence in surgical hand-washing at this stage of the curriculum.

Before this point in the curriculum, students had never had a patient and never performed a structured hand-wash. During the first semester, the students were given a general theoretical review on clinical hygiene. The skills in and the knowledge of hand-washing at the time of the study were therefore very limited.

The students who participated in the study (n=28) were randomly assigned to two groups, an experimental (n=15) or a control group (n=13). The experimental group used the fragmented form of the video and the control group watched the complete one. Both groups were given instructions on how to use the web pages; how to click; and how to start, stop, pause, and navigate in the videos. They were told that they could watch the videos as many times as they liked and in any order they chose. They were also told that they would be assessed in surgical hand-washing 1 week after they had watched the video. This assessment would not affect their end-of-semester examination results. At this time, the students were unaware that they were participating in a study. No other instructions or learning material was provided. Each student used one computer with headphones while watching the video.

Approximately 1 week after watching the video, all students were asked to perform a surgical hand-wash while being video recorded. After the practical hand–wash, the students took a small written test with eight questions on the theoretical part of the video. At that point, the experimental character of the process was revealed to them and they were asked to fill in a questionnaire on their attitudes towards video-based learning.

Parameter of analysis

Logging

The log files of the two web pages were analysed with regard to the total time used by each student watching the video as well as the order in which the students switched between the eight different parts in the fragmented version.

Hand-wash

Two clinicians (one senior and one junior) were asked to blindly evaluate the videos of the students performing the surgical hand-wash, according to predetermined criteria. The clinicians had no association with the students. The students' performance was rated on a scale from 1 to 6 (poor–excellent) for each of the six different stages of the hand-washing process. Furthermore, each of the six stages included several steps which were individually assessed as correct or incorrect, in total 36 steps.

Written test

The written test consisted of eight questions which were assessed as correct or incorrect. The maximum score was eight points.

Attitudes

The students filled in a questionnaire with ten questions regarding their attitudes towards video-based instruction and learning after they had completes all the phases. Seven of these questions were answered on a visual analogue scale (VAS) (0–100 mm), and the remaining three were open text questions. Differences between the two student groups for the questions answered with a VAS were analysed using the unpaired *t*-test.

Study IV (Video training system)

The fourth study aimed to investigate the effectiveness of a computer-based video support in the training of manual skills related to periodontal treatment.

Sample

Eighty-four students (4 males and 80 females) were included in this study. Sixty-two students were dental assistants who had no previous clinical experience in scaling and root planning, while all remaining students were dental hygienists. Eleven of the hygienists had 1 year or less of experience; six had worked in the profession for up to 3 years, while the remaining five had at least 6 years of practice.

The participants in the course were financed by their employers, and several had travelled a long distance. Completion of the course would result in a significant professional advantage.

The sample was randomised into nine groups of 8–11 students each. Five of these groups with a total of 49 students were the experimental, while four groups (total 35 students) served as controls.

Experimental methodology

Both groups underwent a course on conservative periodontal treatment, composed of 43 hours of lectures and 7 hours of practice. As part of this course, a 1-day lecture on instruments for scaling and root planing and their use was offered. One to fourteen days after the theoretical training, a 2-hour practical session followed during which 21 different procedures were tested on phantoms bearing plastic models.

The experimental (E) group was told to use the Visual Training System (VTS) described below, while the control group (C) underwent standard teaching. The standard teaching consisted of a live theoretical presentation with a video camera that projected on a TV screen the movements required for

each procedure, performed on phantoms. The control groups were first allowed to use the VTS for 1 hour, after completion of the study (Fig. 7). In all groups, a theoretical presentation preceded each practical procedure. After the theoretical presentation, students were asked to practice the procedures on the phantoms.

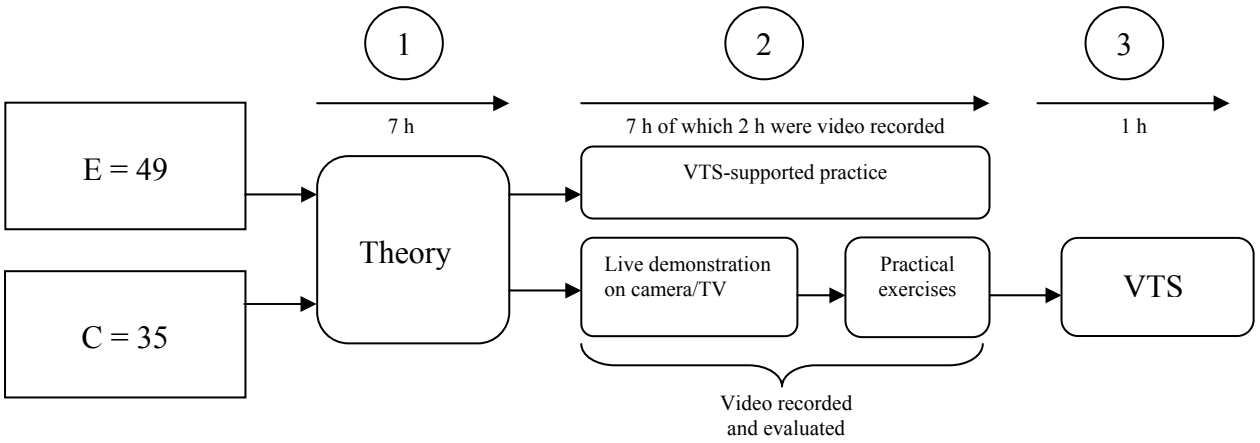

Figure 7. Flow chart of the study. Note that the experimental groups (E) only trained with the visual training system (VTS), while the control groups (C) had live demonstrations. The control groups were allowed to train with the VTS following completion of the study.

Visual Training System

The VTS consisted of a PowerPoint presentation which included still images and video clips. The images were used to illustrate, for instance, the grip of a curette or the finger rest, while video clips demonstrated the correct procedures to be performed. The video clips were 10–20 seconds long. Every single procedure was illustrated by one or two video clips that the students could run back and forth as they pleased, by clicking on the appropriate cursor. The only way to move back and forth among the video pages was by clicking on the corresponding buttons on the video pages themselves. The students were free to use the VTS in the way they found most appropriate for themselves, observing the video clips again and reviewing the procedures already performed. They were not allowed to go ahead by themselves and study the new procedures individually.

Evaluation procedure

During the practical training, all groups were video recorded with two video cameras from different angles. An independent observer analysed the videos. The observer recorded the performance of a procedure as "wrong" when the teacher or the assistant intervened to correct the student according to a predetermined checklist and "correct" when there was no intervention. The scores for each group were compared both in total as well as for each of the 21 procedures.

Results

Study I (Literature review)

Effectiveness of CAL in comparison to traditional teaching

Several studies have shown that groups of students who use CAL have better results than groups undergoing traditional learning (Plasschaert, Wilson et al. 1995; Plasschaert, Cailleteau et al. 1997; Preston 1997; Ayoub, Vanderboom et al. 1998; Hawley, Hamilton et al. 1998). Some studies even demonstrate that students using CAL needed less time to reach the learning objectives and achieved better final results than students who did not have access to CAL (Lyon, Healy et al. 1992; Plasschaert, Cailleteau et al. 1997). Generally, it seems that the more recent a study, the better the results of the study. References from the 1980s found that CAL is as good as traditional education (Mendel and Scheetz 1982) while later references indicate that CAL is better than traditional education (Grigg and Stephens 1998; Cravener 1999; Devitt and Palmer 1999). This could reflect the fact that computers have become faster and graphics, usability, and the capability of combining different media have improved tremendously in recent years. In 1992, however, Clark wrote that many published papers with a focus on technology contained biases. Even those with poor controls found the computer to be superior to traditional teaching (Clark 1992). Advantages and disadvantages of CAL packages as reported by the literature are summarised in table 2.

Advantages	Disadvantages
• The student can choose his or her own path and speed. • The program can be stopped at any time. • The program can be repeated as often as the user wishes. • The computer is not judgemental. The student can learn from his mistakes without feeling any guilt. • The program saves time for the teacher (in the long term). (Grigg and Stephens 1998; Tolidis, Crawford et al. 1998). • The students are more activated (Mendel and Scheetz 1982; Cravener 1999). • Weak students are favoured (Grigg and Stephens 1998; Langer, Schewe et al. 1998).	• The starting costs are high. • The staff needs to be trained. • Students must be familiarised with the medium. (Grigg and Stephens 1998; Cravener 1999)

Table 2. Advantages and disadvantages of CAL packages as reported in the literature.

Attitudes towards CAL among students, staff, and professionals

Student considerations

Survey studies conducted during the 1980s reported significantly different results than those made during the 1990s. In the 1980s, students considered CAL to offer an advantage and be time-saving in comparison to more traditional education (Levine, Jones et al. 1987; Wenzel and Gotfredsen 1997). In the 1990s, the students were significantly more positive and used computers more for learning purposes than they did earlier (Wenzel and Gotfredsen 1997). Studies at dental faculties on two continents report that the majority of students consider CAL challenging and motivating. Even students who have no experience with computers adapt easily to CAL software (Wenzel and Gotfredsen 1997; Lamb and Godfrey 1999).

Those students who have computer experience have a greater belief that CAL can replace lectures (Lamb and Godfrey 1999). Very few dental students in 1995, however, had had the opportunity to use multimedia software with animations in their education (Plasschaert, Wilson et al. 1995).

Many students today have insufficient computer knowledge and do not feel comfortable with

computers. In a study from 1992, students self-assessed their general computer knowledge with a mean score of 1.85 on a 1–5 graded scale. The same students rated the value of computers in dental care with a mean score of 3.91 (Feldman 1992). In a study from 1994, 63% classified their computer literacy as negligible or reduced. Of the same students, 85% thought that computers were important in medicine (Gouveia-Oliveira, Rodrigues et al. 1994). Another study from 1999 showed that 51.1% considered their expertise with computers to be ‘‘poor’’ (Ray and Hannigan 1999). These observations indicate that students realise the importance of computers in the dental field. Thus, even if computers are more common today, computer literacy among students is still low.

Staff considerations

Even teachers thought that CAL was stimulating. However, the low answer frequency (less then 50%) in a questionnaire could indicate that not all teachers think that CAL is an important issue (Lang, Green et al. 1992; Plasschaert, Wilson et al. 1995). It appears that there is a silent majority of teachers whose opinion is not reflected in relevant surveys as they are not interested or competent in the medium (Plasschaert, Wilson et al. 1995).

Professional considerations

The clinician’s acceptance of CAL has been evaluated in program packages of different dental subjects. The educational software received good assessments compared to tapes, books, or journals (Long, Mercer et al. 1994; Pollard and Davenport 1994; Schuhbeck, Hassfeld et al. 1999). An extensive evaluation of CAL packages in Great Britain undertaken between 1992 and 1998 demonstrated gains in perceived levels of knowledge from 70% to 88% among users. The perceived level of skills acquisition, however, was less, between 20% and 57% (Polard 2000).

Updated search

The search located a total of 3,682 articles, whereof 18 met the inclusion criteria. All 18 studies compared the effectiveness of computer-aided learning with another type of learning (e.g. lectures, text, seminars). A summary of the results of these studies is presented in table 3 (next page).

From the 18 randomised controlled trials, 2 were dental and 16 were medical CAL packages. Ten were pure stand-alone, four were simulators, and four were web based.

Four of the studies found statistically significant differences in outcome measures (scores on multiple choice, written, or oral tests and clinical performance) that favoured CAL over the comparison groups, while three documented significant outcomes that favoured the comparison groups over CAL, and nine found no significant differences.

Four of the studies measured the time used for learning. Of these, three reported benefits with CAL, that studying with CAL takes shorter time than without.

Eleven questionnaire studies investigated students' attitudes towards CAL. Ten studies reported positive student attitudes, one negative student attitudes, and one no significant difference (Fig. 8).

All eighteen studies were conducted at the holistic level. Only one seemed to have adequately considered and integrated previous research results in the development of their program.

Ref.	Subject	Study characteristics	Measurements/evaluations	Results
Seabra 2004	Prostate cancer	M / CAL 60 undergraduate medical students E: CAL for 2h C: Lecture for 2h	Multiple choice question post test immediately after exposure.	R: 0 A: +
Maag 2004	Dosage calculation	M / CAL 96 undergraduate nursing students C: Text only E1: Text and image E2: Multimedia E3: interactive Multimedia	Written pre-post math test (directly and 1 week later)	R: 0 A: 0 F: Yes
Tsai 2004	Intravenous injection	M / CAL 81 first-year novice nurses E: Used CAL software three times á 30 minutes C:Orientation Lecture	Written pre-post test (directly and 2 weeks later)	R :+ A: +
Komolpis 2002	Orthodontic instruction and assessment	D / Web-based 99 second-year dental students E: Studied two cases from the website C: Studied the same two cases from traditional orthodontic records.	Comparing test scores and the time spent on the tests	R: 0 A: + F: No
Mc Donough 2002	Exposure therapy for phobias	M / Web-based 37 third-year medical students E: Solo computer C: Group face-to-face tutorial teaching	Multiple choice question Time	R: - A: - T: + F: Yes
Shomaker 2002	Parasitology	M / CAL 94 medical students E1: Computer-based instruction, E2: Combination of computer-based and lecture-based instruction C: Traditional lecture-based instruction	A pre-test, a final examination, and a post-test administered 4 months after the course	R: 0 T: + A: + F: Yes
Lieberman 2002	Radiology	M / CAL 54 third- and fourth-year medical students + 4 first-year radiology residents E: Interactive CAL module C: Interactive tutorial	Pre-post test Test of visual diagnosis at the end	R: - F:Yes
Chang 2002	Intravenous cannulation	M / Simulator 28 nurses E: CathSim (Simulator) C: Plastic arm	Performances on real patients with an intravenous cannulation qualification using a validated checklist	R: 0 A: + F:Yes
Lowe 2001	Index of Orthodontic Treatment Need	D / Web-based 85 third-year undergraduate dental students E: Seminar and CAL C: Lecture and seminar	Standard Post test	R: +
Holt 2001	Endocrinology	M / CAL 185 first-year clinical medical students E: Same material available (as C) through CAL C: Series of conventional lectures	Pre-post multiple choice test	R: 0 A: +
Jeffries 2001	Oral medication administration	M / CAL 42 junior baccalaureate nursing students E: Interactive, multimedia CD-ROM program C: A scripted lecture, in addition to an 18-minute videotape	Pre-post test	R: 0 A: + T: + F:Yes
Vichitv-ejpaisal 2001	Arterial blood gas interpretation	M / CAL 80 third-year medical students E: CAL C: Text group	Pre-post test; immediately and after 3 weeks	R: - F:Yes
Williams 2001	Psychiatric knowledge and skills	M / CAL 166 undergraduate medical students C: A structured lecture E: CAL	Test Objective measure of assessment skills	R: 0 Skill: + A:+ F:Yes
Maleck 2001	Radiology	M / CAL 255 second-year medical students E1:Computer-based cases with interactive elements E2: Computer-based cases without interactive elements E3: Paper-based cases with interactive elements C: No exposure to the cases	Multiple choice test	R: 0 A:+ F: Yes
Schwid 2001	Anaesthetic emergencies	M / CAL 31 first-year clinical anaesthesia residents E: Intervention group handled 10 anaesthetic emergencies C: Study a handout covering the same 10 emergencies.	Four standardised scenarios in a mannequin-based simulator	R:+ F:Yes
Gilbart 2000	Trauma management skills	M / Simulator 139 fourth-year clinical clerks. E: Computer-based simulator C: Seminar-based teaching groups	OSCE	R: 0 A: + F:Yes
Bell 2000	Family medicine and internal medicine	M / Web-based 162 medical students at four different universities E: CAL tutorial system C: Printed materials	Scores on multiple-choice knowledge tests, score gain per unit of study time, and ratings on a learner satisfaction scale	R: 0 A: + T: + F:Yes
Jordan 2000	Laparoscopy	M / Simulator 24 medical students E1: Minimally invasive surgery virtual reality E2: Randomly alternating between y-axis inverted and normal laparoscopic images C: Normal laparoscopic imaging condition.	Perform a 2-minute laparoscopic cutting task before and after training	R: + F:Yes

Table 3 (on page 34). Overview of all randomised, controlled studies between January 2000 and July 2004 that met the inclusion criteria described in Materials and Methods on page 16.

Study characteristics
***D**: Dental field; **M**: Medical field; **E**: Experimental group; **C**: Control group;**CAL**: Stand-alone application; **Web-based**: Software used on the Internet; **Simulator**: Specially designed, computer-controlled devices such as dummies or force feedback devices.*

Results
***R**: Test result; **A**: Attitudes towards CAL; **T**: Time spent on learning; **F**: Feedback provided by the software to the students; **0**: No significant results; **+**: Significant advantage of CAL; **-**: Significant disadvantage of CAL.*

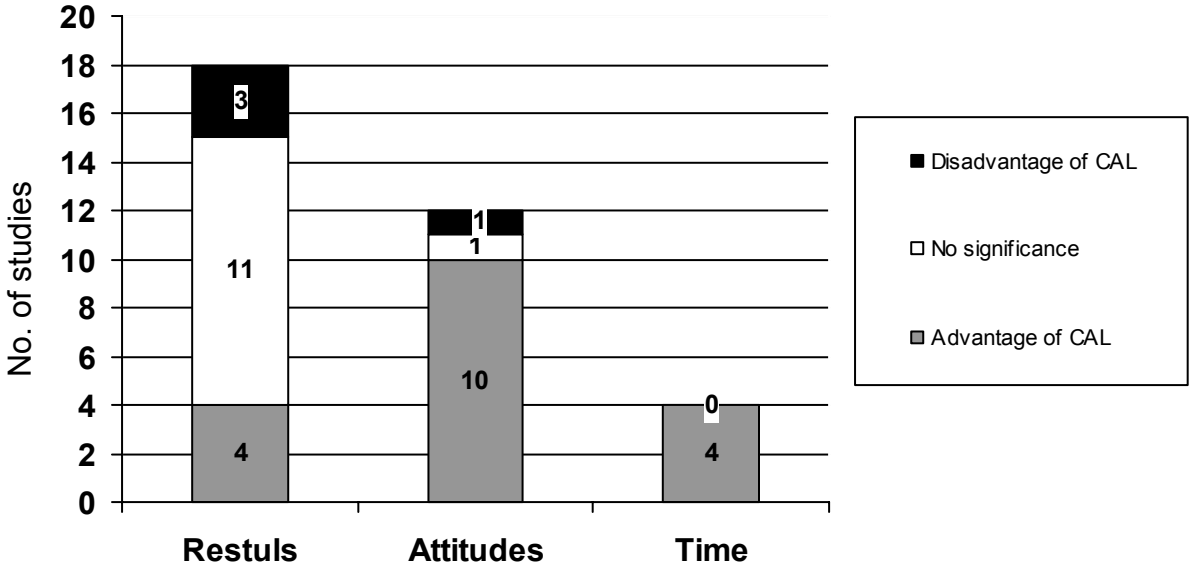

Fig 8. The 18 studies between January 2000 and July 2004 that met the inclusion criteria stated on page 16 (Materials and Methods). Distribution of studies according to results, students' attitudes, and students' study time.

Study IIa (Design and usability test)

The students asked 142 questions in total (Fig. 9), of which:

- 72 (51%) were understood directly by the computer.
- 53 (37%) were correct but missing from the database (not all of the questions were relevant to the case).
- 6 (4%) were incorrectly asked.
- 11 (8 %) were correct but unanswerable by the virtual patient database technique.

The 53 questions that were correct but missing from the database were later added with answers.

On average, the students took 20 minutes to record the history of the virtual patient and asked 20 questions.

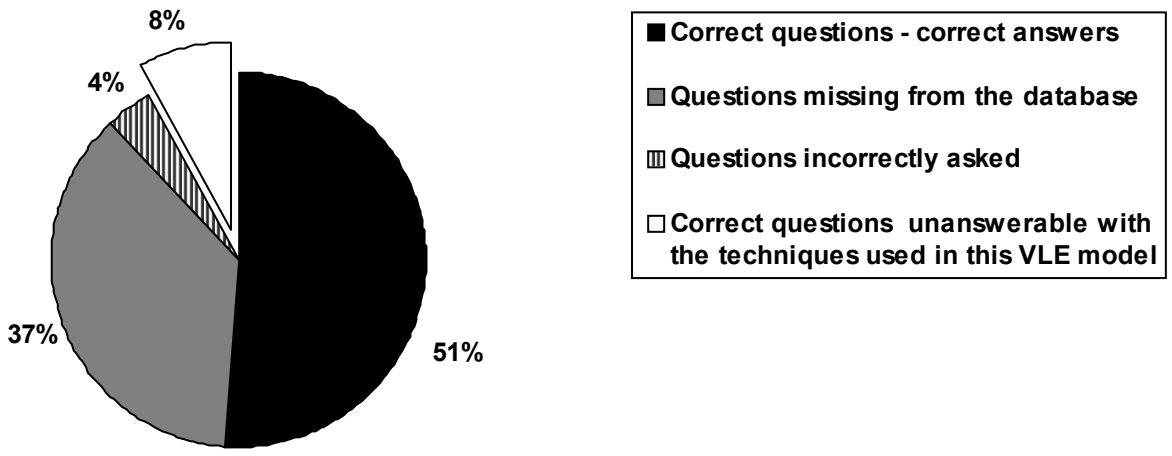

Fig 9. Pie chart illustrating the proportions of different types of acceptable and unacceptable questions asked the virtual patient by the students in the usability test of this virtual learning environment (VLE).

Study IIb (Virtual learning)

The students in the experimental group took 20 minutes on average to practice history taking with the virtual patient.

Use of time

The students who had worked with the virtual patient spent significantly more time talking with their real patient before needing to consult their notes (E: 6:39) compared with the other students in the control group (C: 3:43). In terms of total time used for medical-dental history taking, however, the difference between the two groups was non-significant (E: 8:04 versus C: 6:04) (Fig. 10).

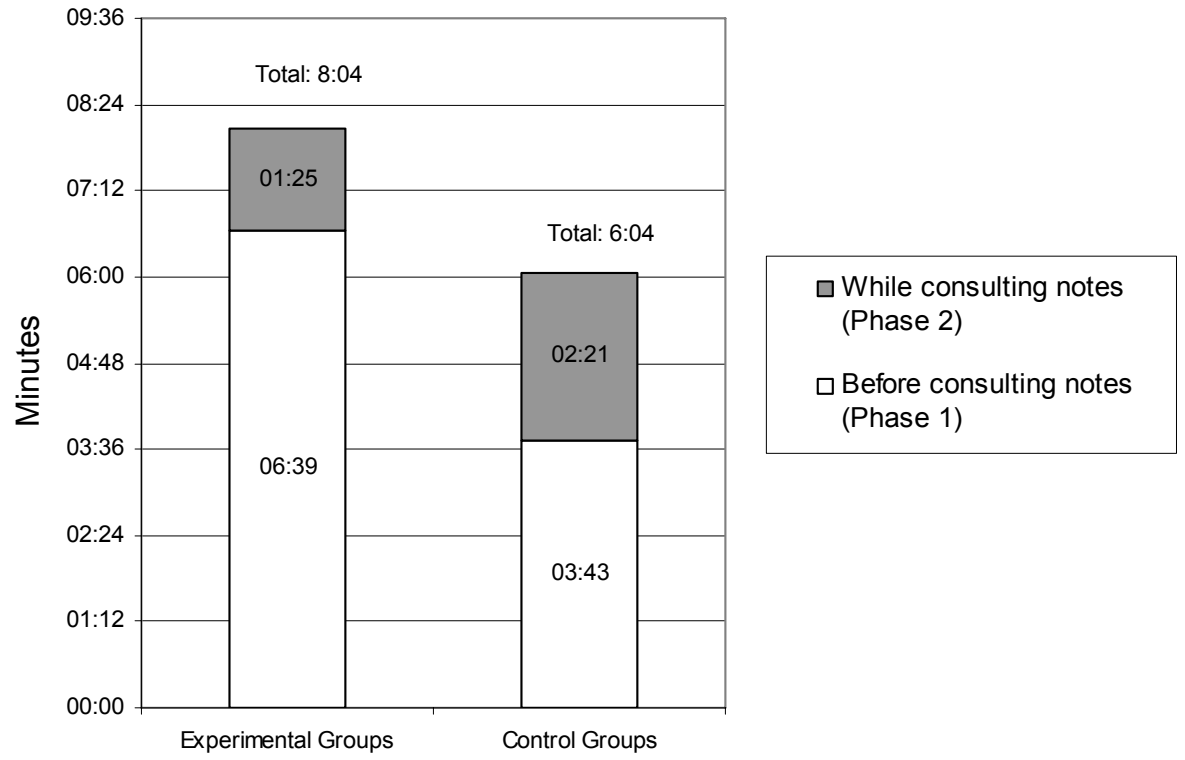

Fig. 10. Illustration of the time used by students who had and who had not practiced history taking with the virtual patient prior to their very first patient encounter. Note that the students who had used the virtual patient used significantly more time to question the patient ($p < 0.01$) prior to consulting the medical record form. Total times, however, differed non-significantly ($p > 0.1$).

Analysis of questions asked

Qcr: The experimental group asked significantly more critical questions in phase 1 compared to the control group (E: 10.06 versus C: 6.61) as well as a significantly higher number of Qcr in total (E: 10.50 versus C: 8.70) (Fig. 11).

Qte: Students in the experimental group also asked significantly more questions in phase 1 than the control group (E: 16.06 versus C: 10.26) and fewer questions in phase 2 (E: 1.63 versus C: 4.43). The difference between the groups in total number of questions asked, however, was non-significant (E: 17.69 versus C: 14.69).

Qti: Although the total numbers of questions asked by the students in the two groups were comparable (E: 31.19 versus C: 24.52), the students who had trained with the virtual patients asked a significantly higher number of questions before consulting the history form (E: 26.19 versus C: 15.96).

Professional behaviour

Students who had trained with the virtual patient received significantly higher scores than those in the control group concerning professional behaviour (E: 5 versus C: 4) on a six-grade scale.

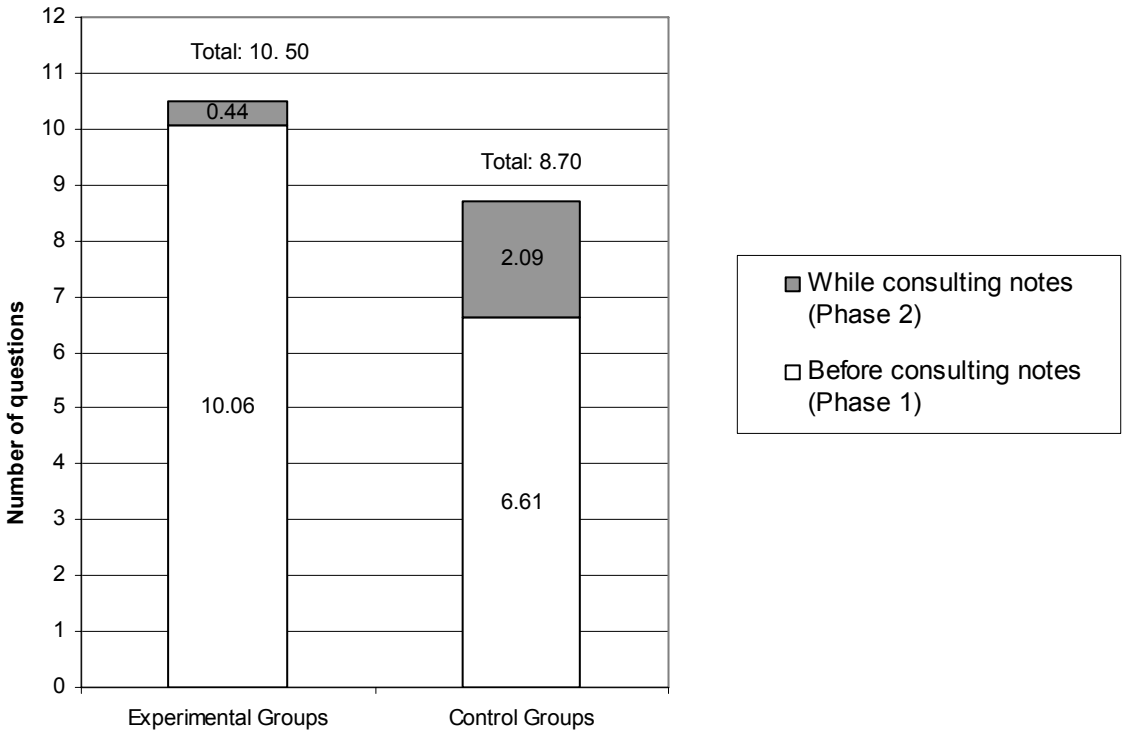

Fig 11. Illustration of the number of critical questions (Qcr) asked during phase 1 and phase 2 by students who had or had not used the virtual patient prior to their first patient encounter. The differences in numbers of questions during phase 1 between the two groups were significant ($p < 0.0001$) as was the difference in the total number of questions ($p < 0.02$).

Study III (Segmented video vs. whole)

The students in the experimental group watched the instructional video on hand-washing significantly longer (15'20") than the control group (9'41") $p < 0.0001$ (see table 4). Most of the students in the experimental group initially watched clips one to eight in a linear fashion; thereafter they jumped between the different clips according to their own priorities. None of the clips appeared to be favourised.

Differences between the scores of the two assessors for the two groups were non-significant (see table 4). The experimental group had significantly better results (7.3) in the written test than the control group (6.33) $p<0.05$ (see table 4).

	Range	**Experimental**		**Control**		**Significance**
Time watching the video(s)	-	15'20" (SD: 3'21")		9'41" (SD: 3'55")		p<0.0001
Grade (median)	1-6	S: 5	J: 5	S:5	J: 5	ns
Score (mean)	0-36	S: 25.7	J: 24.1	S: 25.6	J: 23.3	ns
Written test	0-8	7.3 (SD:1.4)		6.3 (SD:0.7)		p<0.05

Table 4. Summary of the results of the different steps of the evaluation.
ns = statistically non-significant difference; ***S****=Senior evaluator;* ***J****=Junior evaluator*

The VAS revealed no significant difference between the groups concerning attitudes towards the use of video for learning. Most students in both groups expressed satisfaction with the use of video for learning. The main advantage in both groups was judged to be the option of learning at one's own pace. The disadvantage was the lack of personal contact with a teacher. The students in both groups also suggested that practice should follow directly after the video instruction.

Neither group was very positive about the possibility of video instruction replacing all other forms of teaching. The students in the experimental group, however, tended ($p<0.06$) to be more positive than the control group (see table 5).

	Question	VAS endpoints	E	C
1	How do you judge your own learning from watching the video(s)?	Learned nothing – Learned everything	69	66
2	How do you like watching videos on your own (not on TV together with your fellow students)?	Very bad – Very good	77	82
3	How user friendly were the web pages?	Very user-friendly – Not user friendly	88	93
4	How did you like watching segmented videos?	Very bad – Very good	88	-
5	What do you think about instructional video as a tool in teaching?	Very bad – Very god	83	82
6	Do you think video could replace all other forms of teaching?	Not at all – Replace completely	44	25
7	If instructional videos in general were accessible over the Internet, to what extent would you on your own accord watch them to prepare yourself prior to a clinical procedure?	Never - Always	84	79

Table 5. Answers to the attitude questions on the VAS scale (0–100 mm). Question four was only given to the experimental group. Differences between the experimental (E) and the control (C) groups were non-significant.

Study IV (Video training system)

A total of 735 scores (35 students in 21 procedures) were collected from the control groups and 1029 scores (49 students in 21 procedures) from the experimental groups. A Mann-Whitney U test revealed that students' overall performance in the experimental group was significantly better (p <0.001) than in the control group. The same analysis for each of the 21 procedures demonstrated significant differences between the groups in the performance of 9 of the 21 procedures (table 6). In all 9 cases, students of the experimental group performed better than their colleagues in the control group.

Procedure	**Difference (*p*-value)**	**Procedure**	**Difference (*p*-value)**
Colour application	ns	Sickle sharpening	0.0116
Gracey sharpening	0.0205	Probing	ns
Quadrant 1		*Quadrant 3*	
Scaling Q1 11/12	0.0112	Scaling Q3 11/12	ns
Scaling Q1 13/14	ns	Scaling Q3 11/12 "Alternative position"	ns
Scaling Q1 7/8	0.0034	Scaling Q3 13/14	ns
Scaling Q1 13/14 "Turned upside down"	0.0075	Scaling Q3 7/8	ns
		Scaling Q3 13/14 "Turned upside down"	ns
Quadrant 2		*Quadrant 4*	
Scaling Q2 11/12	ns	Scaling Q4 11/12	0.0071
Scaling Q2 13/14	0.0006	Scaling Q4 11/12 "Alternative position"	ns
Scaling Q2 7/8	0.0327	Scaling Q4 13/14	ns
Scaling Q2 13/14 "Turned upside down"	ns	Scaling Q4 7/8	0.0293

ns = non-significant difference

Table 6. Differences in performance between the experimental and control groups in the 21 procedures evaluated, in chronological order.

Discussion

Computers are receiving more and more attention as educational tools. Despite the explosive spread of computers and the use of Internet, research on the effectiveness of computer-based learning remains limited, especially in the areas of healthcare and clinical education (Schittek, Mattheos et al. 2001). Early research, undertaken when CAL was introduced, reported contradictory findings concerning learning outcome (Mullaney, Smith et al. 1976; Mendel and Scheetz 1982). In the 1990s, research reported enthusiastic results (Fouad and Burleson 1997; Plasschaert, Cailleteau et al. 1997) while the latest research indicates a more cautious approach (Howerton, Platin et al. 2002; Komolpis and Johnson 2002).

Since the first review in 2000 (Schittek, Mattheos et al. 2001), numerous new articles in the field of CAL have been published. The trend today, however, seems to be more "cautiously positive" towards CAL. The number of positive articles is lower than previously, and the explanation put forth in the first review for why the trend seemed to be increasing—because of the constant improvement in computers since the 1980s—does not seem to be valid 4 years later.

One of the possible factors leading to the somewhat negative trend observed in recent years could be that tools for faculties to develop their own CAL software have become widespread, popular, and more user friendly. Institutions and individuals have therefore been trying to develop their own software,

and they have not always been able to take full advantage of the computer's pedagogical potential. The new development packages have encouraged many with insufficient experience to undertake the development of CAL applications.

Educational software designers often underestimate the importance of programming and pedagogical principles such as presentation of the material, interactivity, and feedback. Simplicity of design is a critical issue in computer-based learning (Nattestad, Attström et al. 2002). This is even more important considering the low level of computer competence often encountered among students (Grigg and Stephens 1999; Mattheos, Schittek Janda et al. 2005). The success of even well designed, computer-based courses has been jeopardised by complicated and difficult designs (Mattheos, Nattestad et al. 2001). In early computer applications, development was a task for a group of professionals, which more often than not led to relatively successful results in learning outcome. It is probably not by coincidence that the software used in the four studies in the updated literature review demonstrated positive results; they were most likely developed by a team of professionals.

Interestingly enough, only one of the studies in the updated review clearly stated which previous research results (at the basic level and at the component level) they used to design the software. Also, all articles represented research conducted at the holistic level. There is an apparent lack of research at the component level, an approach that in most disciplines would precede research on a holistic level. In a perusal of the literature and studies that reproduce screen dumps of the software produced, there often seems to be a lack of knowledge of layout. This lack of proper design could make learning more difficult, which would be disadvantageous for a positive outcome with CAL. The learning process is complex (Regehr and Norman 1996). Single factors alone or together with others could be critical for success. Sites designed according to principles derived from psychological research have been shown to be superior to sites that violate these principles (Dalal, Quible et al. 2000).

To give the learner an effective, good, and fast tool for learning through a computer, the programmer must know what effect the different components of the program have on

the learning process. This implies a need for a review that collects data on pedagogical and programming issues related to CAL. Application of adjusted design principles ranging from simple details such as font size and colours to more advanced characteristics such as interactivity and modes of feedback would be helpful in the future design of software and would probably improve the number of positive results. It is not always that the "traditional aesthetic rules of the arts" are valid in computer design. Dividing the screen according to the "divine proportion" or "golden ratio" was, for instance, shown by van Schaik (van Schaik and Ling 2003) to be least desirable. Even if the importance of aesthetics has long been recognised in the arts, researchers have only recently begun to investigate the implications of aesthetics for the development of visual displays (Dalal, Quible et al. 2000; Ngo 2001). Why is it that when we use simple CAL software (e.g. which in principle puts a textbook on the screen), we prefer to print out the pages instead of reading from the screen?

One of the goals of the Global Conference of Dented in 2002 was to agree on standards and suggestions on how CAL software should be designed and programmed to be as powerful a learning tool as possible (Nattestad, Attström et al 2002). As a result of this meeting, certain needs were identified and research tasks described to investigate how a CAL software is best designed. Most of these research tasks belonged on the basic and holistic levels. At the Slice of Life Congress (in Münich, Germany, 2001) a group was also formed to address the same issues.

Constructive feedback to the learner is a crucial factor in the learning process (Epstein and Northrup 1994; Taras 2001). The ability of computer applications to provide the learner with immediate feedback is therefore expected to be one of the major benefits of CAL (Mattheos, Nattestad et al. 2004). This expectation, however, was not verified in the updated review; software applications that provided feedback did not seem to lead to better results then those without. The different types of feedback used in the studies reviewed are often not clearly described. Sometimes, "feedback" is limited to scores reporting the total number of correct answers to multiple choice questions or quizzes. Simulators, however, provide learners with what could be called "interactive feedback". This means that the software or "dummy" adjusts feedback to the actual actions

of the user, resulting in different outcomes; this is more than simply providing the correct answers or reporting a score. Such "interactive feedback" should enhance the learning process more than just a quiz. Resnik et al. state that human-like feedback from a computer is better than plain computer feedback (Resnik and Lammers 1985).

The results of the three studies that reported negative results (from the updated review) were marginally but significantly lower, disadvantaging CAL. Most articles reported no differences. Both the control and experimental groups had similar or significantly higher after-test scores. This, of course, raises the question of cost-effectiveness, which most articles conclude. Today, most faculties are equipped with the computers needed to run CAL packages, which means that procurement costs of hardware are nearly non-existent. Nevertheless, software development and time are still needed.

The students' attitudes towards CAL are still positive today. The only negative article concerned psychology students. Psychology students value being able to "discuss", which is impossible with a computer. Though, students in general seemed eager to try the new pedagogical tool. One observation is that the time to learn with CAL seems to be shorter than the time needed with other learning forms.

Many of the studies that did not fit the inclusion criteria reported positive learning outcomes (Rehbein, Hiinostroza et al. 2002; Watterson, Beiko et al. 2002; Mileman, van den Hout et al. 2003).

None of the studies evaluated the long-term effectiveness of learning, which indicates that more studies are needed.

The conclusion of the first review still stands. Ideally, CAL should not be used as a free-standing educational tool, but rather as a supplement to traditional education.

Components

Video

The results of the third study indicate that the differences in learning outcome between viewing instructional films in one complete video or in segments are significant. The students in the experimental group watched the video segments significantly longer than those in the

control group. This is in contrast to the observation that both groups performed equally well in the practical tests. Previous studies have indicated that the time spent per task relates to learning outcome (Mattheos, Nattestad et al. 2004). The tasks to be learned in the present study may have been too simple to reflect a difference in learning outcome. Other studies have shown segmented videos to be effective when the procedure was practiced directly after the student had viewed each single clip (Tani Botticelli, Schittek Janda et al. 2005). Also, the method of recruiting students for the study might have selected those most motivated. Furthermore, students in the control group spent approximately 9 minutes viewing the 6-minute long film. This observation indicates that the students would stop the film and rehearse some parts of the instruction before continuing to view the rest of the film, thereby imitating the principle of the segmented videos.

There was a high acceptance of video as a learning resource, especially when it was available over the Internet. The students stated that they liked the idea of being able to access educational material over the net so that they could view the videos on demand. The students further pointed out that if there were instructional videos on the net, they would be able to prepare themselves for the clinical sessions better. Taken together, the students' comments regarding the feasibility of using video for learning clinical behaviour were very positive.

Apart from practical reasons, this method of delivery might improve the learning outcome of instructional video. An educational strategy that is supposed to enhance memory retention should focus on meaning, reduce dependence on context, and provide options for repeated retrieval of the information or practise (Regehr and Norman 1996).

By presenting the video in clips, the user acquires full control of the flow of information and is able to direct her or his attention as she or he feels necessary. The learner can therefore prioritise, stop, or repeat the flow of information for each part of the video separately, keep notes, and proceed at her or his own pace.

On the other hand, a complete sequential video, especially when seen without pause, imposes a predetermined flow of information on all users and might not be suitable for everyone. It gives the learner little chance to control the process, and distractions such as taking notes might result in losing part of the

information continuously presented by the video. There were four students who took notes while watching the movies (three from the experimental group and one from the control group). These four students performed very well in the tests. Because the segmented movies contain natural stops, it is easier to make notes.

Students expressed the need to practise directly after watching the video. This was tested in experimental study IV, which showed that the use of chair-side video training support improves psychomotor skills related to initial periodontal treatment. These observations are in accordance with previous studies that also employed a chair-side principle for the instructional use of video (Renton-Harper, Addy et al. 1999; Addy, Renton-Harper et al. 1999).

In various fields of medicine, dentistry, and patient instruction, the use of video instruction (VI) has given positive results in terms of learning outcome (Renton-Harper, Addy et al. 1999; Addy, Renton-Harper et al. 1999; Oermann, Webb et al. 2003). VI was shown to be more effective than written instructions. For example, plaque removal with an electrical toothbrush was significantly better when the patients were instructed with VI rather than given written instructions (Renton-Harper, Addy et al. 1999; Addy, Renton-Harper et al. 1999). VI was also shown to be more efficient in terms of long-term effectiveness and skill retention (van der Palen, Klein et al. 1997).

There are, however, some studies that find no differences whatsoever in pure VI vs. lectures (Packer, Rogers et al. 2001; Mir, Marshall et al. 1984). Many times, students rated live instruction higher than video, mostly because of the opportunity to ask questions and interact with the instructor (Bazyk and Jeziorowski 1989). In one study, a combination of live lectures and VI was rated high and produced the largest gains in self-efficacy (Froman, Hence et al. 1993). In the present study, there was a combination of personal contact with feedback and the use of VTS.

The VTS was based on the principles of short video clips, chair-side access, and interactivity in the sense that the user had full control of the presentation of the learning material. This is in contrast to most previously used video instructions, which often presented the material as a sequential film (Packer, Rogers et al. 2001; van der Palen, Klein et al. 1997).

It is important to notice that video is a technique undergoing fast development. New methods of delivery are being designed, and it is already possible to film in 3 dimensions. This technique makes it possible to run a film and at the same time freely move around the object (Würmlin, Lamboray et al. 2003). The new methods and techniques presented imply a need of more research (Shephard 2003).

Free text communication

The programming principles and the results of the subsequent usability test on students indicate that it is possible to use FTC in virtual patients in dental education. This is in accordance with experience in the field of medical education and simulators (Sensi and Merlitti 1995). Most other patient simulators operate on the basis of student selection of the items listed. By necessity, some of the choices presented are unnecessary or false. The use of listed items also gives priority to the cognitive process of simple recognition, as do multiple-choice questions. The computer evaluates the item selections made and presents feedback to the student. The learning effectiveness of this latter principle is considered to be limited. Retrieval of knowledge by listed items is poor, unless the list is shown again (Mandler, Pearlstone et al. 1969).

The option of free text and free choice communication with the computer forces students to reflect on what they know and what they do not know in a more active way, because they have to formulate their questions in writing and type the conclusion of their thinking. Text-based, computer-mediated communication is a particularly demanding cognitive task that requires the user to invest substantial processing resources in its attendance (Wickens 1984). When using this means of communication, students must reflect, organise, and prioritise their thoughts. In cognition sciences, this process is considered to increase learning and facilitate future retrieval of understanding and knowledge (Regehr and Norman 1996). As a result, one would expect an inferior outcome if the software was to function with voice recognition where the student could verbalise the questions. According to Reid et al., verbal communication is less demanding than computer-mediated, text-based interaction. The use of voice may allow the student to use a more unstructured and less reflective way of communication than when writing (Reid, Malinek et al. 1996).

Voice communication would benefit the brainstorming process rather than the use of a slower, prioritised, and structured way of thinking. On the other hand, the use of voice would probably increase the number of wrongly asked questions, which might lead to more frustration for the student.

The results of the present studies indicate that students who have had the chance to practise with FTC prior to their very first patient encounter behave in a more knowledgeable and professional way compared to students who have only undergone traditional teaching concerning history taking of dental patients. Thus, the FTC students used more time and asked more questions as well as more critical questions prior to consulting the printed history record. Also, the FTC students received higher scores for professional performance. It was, interestingly, a teacher who was in no way associated with the study and who evaluated the videos blindly who scored the students. These findings indicate that the use of FTC stimulates students to organise their knowledge and behave with more self-confidence in their encounter with the patient. It might be that they did not need to concentrate as much on the questions per se as did the students in the control group. Instead, they could focus on the emotional aspect of history taking and concentrate on behaving with a professional attitude.

Some of the students spontaneously commented on the frustrating experience that the virtual patient did not understand some of their questions. At the same time, this fact gave them a chance to reconsider and to rephrase the question. Thereby, they reflected on the issue and learned to pose the questions in different ways, which they considered to be an advantage.

An important aspect of the virtual patient is that the student does not have to face the risk of asking irrelevant questions. The student can move backward and forward, rethink, and in that way be better prepared for meeting the real patient. In addition, the virtual patient does not judge the student negatively following mistakes (Grundman, Wigton et al. 2000; Schittek, Mattheos et al. 2001).

It is important to note that with the present experimental design, the test group had one more training session prior to their first patient encounter. However, the time used on FTC was around 20 minutes per student. This means that a short period of practise using an FTC for training history

taking results in a significant change in behaviour versus the students in the control group. This observation underlines the potential of virtual learning environments for healthcare personnel and gives great cost-benefit perspectives for using computer-based virtual scenarios for effective learning.

Closing remarks

There are four fundamental requirements for replacing a current teaching method with a new teaching method, technology or strategy:

1. Rapid and easy development
2. Less expense
3. Greater ease of delivery
4. Improved pedagogical results

(Andrew, Benhow 1997)

In today's low-priced computer environment, CAL easily fills the first three requirements that a new teaching method should meet before being considered for adoption. A large variety of free software for developing virtual classrooms and CAL software is available over the Internet. Many faculties have already developed some kind of web-based platform to use to communicate learning materials to their students. The fourth requirement still needs some work. For students to use CAL software as a real learning tool and not because it is a novelty, the software must offer something that a book, lecture, or teacher cannot offer in realistic learning settings. To simply "copy" a textbook with some interactive links will probably not improve pedagogical results.

Students learn in different ways. Some students like to "do" things to learn, some like to read or write to learn. There are today simple tests that can reveal a student's learning style. If this principle were incorporated in CAL software, the usage and acceptance of CAL as a part of a learning strategy would probably rise dramatically. In this sense, the software would define the student's learning needs and present the content in a way best fitted for the individual student's learning style. Although most studies show that students' attitudes towards CAL are positive, students still don't think that CAL can replace traditional teaching (Seabra, Srougi 2004; Schittek Janda, Tani Botticelli 2005) and would rather see CAL used as a

supplement to traditional teaching methods.

In the future, E-learning environments should build on research from the basic and component levels to a greater extent.

Conclusions

- Research-based development of CAL components would increase the potential of CAL in education.
- The use of FTC may enhance education and provide learning opportunities that are not provided in traditional strategies in realistic settings.
- Videos that are segmented seem to give a better learning outcome and are watched longer than unsegmented videos.
- Videos that are incorporated in virtual classrooms, web pages, CAL, or other learning materials would ideally be presented both as a segmented video and as a whole video to give the student a choice.
- At its present level of development, CAL should be used as a supplement to traditional pedagogical methods in academic learning.

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