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Review Article

Computer assisted learning. A Review

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Since 1980 the amount of medical information has doubled approximately every second year. This implies that oral health students as well as professionals need to manage the flow of information rationally, in order to learn how to undertake evidence-based decision-making for diagnosis and treatment in a given patient situation. Current research indicates that computer connected databases and computer assisted learning (CAL) may enhance learning and provide the clinician with information for decision-making when treating patients. Multimedia for CAL, which combines audio and visual data in an interactive form, has proved to be an effective tool in education. CAL may supplement and reinforce more traditional learning and create opportunities to illustrate clinical situations in an interactive way. CAL has the potential to help students develop skills and knowledge. Students, staff and professionals consider CAL stimulating and motivating. Students easily adapt to CAL although their current computer literacy is still low. New authoring tools make it easier for faculties to develop their own CAL software. In the future we will see more sophisticated software with virtual patients who can communicate and interact with the student in a very realistic way. The software will even "step out" from the screen and help the student with clinical procedures. However, at present CAL should not replace traditional education, but rather be used more as a supplement and for self-directed studies.

Key words: computer assisted learning; computer aided learning; computer aided instruction; health education; effectiveness of learning.

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COMPUTER Assisted Learning (CAL) has been a term of increasing significance during the last decade and can also be referred to as Computer Based Instruction (CBI), Computer Aided Learning (CAL), or Computer Aided Instruction (CAI) (1). For the purpose of this review, we can simply define CAL as the learning procedures and environments facilitated through computers. However, the keyword for understanding CAL is interaction. Computers can facilitate interaction during the learning process on multiple levels. On one level we have interaction of the student/user with the content and the learning material (for example with an interactive patient on a CD-ROM). On another level, computers can host interaction of the student/user with the tutor, peer interaction or interaction between members of whole "virtual" learning communities.

The concept of interaction with content was first introduced in applications as early as the 1980's and is probably the best studied aspect of CAL (2). Computers' facilitation of interaction between humans, however, has only emerged during the last decade, as explosive technological progress and the Internet allowed reliable and inexpensive communication. Computer mediated human-human interaction is a whole new area in CAL, which presents special methodological considerations and requires separate study (3).

The present review will be focused on CAL applications where interaction is limited between the user and the content, as the educational experience with these applications is wider, and their future prospects are also remarkable. These CAL applications were initially designed for local use as part of the traditional curriculum. However as both technology and educational experience mature, the real potential of these programs unfolds in distance learning. It is important to remark that although interactive CAL programs are accessed from different places, they are directed by the same educational principles. For instance an "interactive patient" can be accessed through a CD-ROM in the university ICT lab supplementing the local curriculum, and the same application can be available on the web as part of a distance learning course. In both cases, the learning principles and methodological implications are identical, as long as the interaction remains between the user and the content. Therefore study of this kind of application even if in a local environment, is directly applicable to the use of CAL in distance learning, where the future of the medium undoubtedly lies.

The present study aims to summarise the current experience in the field of CAL applications in health education. The review is particularly focused on educational value of CAL, as well as its effectiveness in comparison to traditional teaching. In addition, we intend to investigate the attitude towards CAL among the students, staff and professionals. Finally, visible future trends and developments in the field will be presented.

A brief historic review

In the 1950s computer use was introduced in education. At that time multimedia did not exist as we known it today. Interaction with computers was available by means of slides and audiotapes. The computer mainframe was connected with terminals that were placed relatively far away from the main computer. The computer was used as a knowledge-bank of questions by which students could undertake self-assessment of their knowledge (4). In the early 1970s the use of computers increased. The mainframes were very expensive and difficult to use. It was not until august 1981, when IBM presented the microcomputer IBM PC (personal computer) that the use of computers for educational purpose started to develop. Reports in the British Dental Journal were optimistic regarding the computer's future role in dental education and in the dental clinic (5).

One of the first CAL programs in dentistry was developed by Luffingham in 1984. He used an Apple II 48K PC to control a videotape and allow students to answer simple multiple-choice questions. His conclusion from this study was that CAL provided the student with a popular and effective way of learning (6). Computers have been used in clinical practice for about 15 years. In spite of this, few dental faculties have appropriately prepared the students for using programs and applications that are available for dental clinics (7). There are today a number of CAL programs available on the market. However it seems that the development of CAL is based on the work of very few individuals rather than being a part of the faculty's ICT strategies (8).

The recent progress of communication technology and the wide introduction of the Internet have added a whole new dimension to CAL. Tools to gather information through the Internet provide great opportunities for searching literature and establishing fast communication with international resources. Contacts can be made with colleagues and resource persons in spite of geographical restrictions (9, 10).

The Internet already hosts an increasing variety of programs and databases, making them available for effective and inexpensive distance learning to all kinds of dental students and professionals (11). From on-line tutorials and tests to case studies, simulations and interactive patients (12, 13), the ever-increasing number of available CAL applications on Internet has already shaped the future of the medium in oral health education. In addition, recent software and web design tools allow content experts to design high quality multimedia CAL packages, without the need of expensive technology or technical expertise. These developments are expected to boost CAL production even further. Therefore, evidence-based study and research on CAL in dental education and the relevant educational and methodological implications are urgently needed, if we are to utilize the full potential of the medium.

CAL in dentistry

Current CAL software in dentistry

Learning

CAL provides an effective way of learning. The program in the computer guides the student through an interactive document that integrates text, 2D- as well as 3D-images, video, sound, animation and individual interactions. The student is able either to follow a given path or to design his individual path within the learning material, according to his own learning objectives. Many of the programs place the student in an interactive role as a diagnostic dentist. The program evaluates the student's diagnosis depending on what facts have been accessed (9, 14–16). Some of the programs are built on to the principles of the Problem Based Learning (PBL) system (17).

There are a wide variety of CAL programs available on the market, ranging from very simple to advanced. Many of the programs have been scientifically evaluated with varying results. Most aim at diagnosis and decision-making. Evaluated packages are available in some of the following subjects:

- Anatomy (1)
- Radiology (4, 18)
- Orthodontics (6, 19)
- Prosthodontics (9, 20)
- Periodontology (21)
- Implantology (22)
- Endodontics (14, 16)
- Trauma (23)

- Cariology (9, 24)
- Taking a biopsy (19)
- Pathology (25)

Teaching students how to chart teeth offers a simple example of the practical use of CAL. Students have problems with the reversal of right and left sides in the mouth when moving the information into charts. A program was developed in which the student could look at pictures with lesions and then practise putting the results in an electronic record. The evaluation showed that the students who had used the computerised education had 80% better results in pre- and post-tests compared with only 39% in the control group (24).

Pre-clinical education can also be accomplished by using computers. Existing software can teach preparation of teeth for fillings and crowns. The computer program follows the student's preparation while it is in progress, reproducing it afterwards in a 3D-image. This 3D-image is used to study different aspects of the student's accomplished work (9).

Examination

Recently, efforts have been made to use computers in examinations. There are a few programs available on the market for examinations. Few scientific studies have been conducted in the field of examination in health care education. Only some applications are found in the literature (18). These programs often use multiple-choice questions as a test.

Attitudes towards CAL

Student considerations

Survey studies conducted during the 1980s, demonstrate significantly different results than those made during the 1990s. In the 80s students considered CAL to offer an advantage and be time-saving in comparison to more traditional education (4, 25). In the 90s the students were significantly more positive and used computers more for learning purposes than they did earlier (4). Studies at dental faculties in two continents have confirmed that the majority of students consider CAL challenging and motivating.

Even students who have no experience with computers adapt easily to CAL software (4, 26). Those students who have computer experience have a greater belief that CAL can replace lectures (26).

However, very few dental students have tried multimedia software with animations during their education (8). This may be because many students today have insufficient computer knowledge and don't 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 (7). In a study from 1994, 63% classified their computer literacy as negligible or reduced. Of the same students, 85% thought that computers are important in medicine (27). Another study from 1999 showed that 51.1% considered their expertise with computers as "poor" (28). These observations point out 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%) on the questionnaire could indicate that not all teachers think that CAL is an important issue (8, 29). 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 (8).

Professional considerations

The clinician's acceptance of CAL has been evaluated in program packages in different dental subjects. The software received good assessments compared to tapes, books or journals (19, 20, 22). An extensive evaluation of CAL packages in Britain, undertaken from 1992 until 1998, demonstrated perceived levels of knowledge gain from 70% to 88% among users. The perceived level of skills acquisition however was, shown to be between 20% and 57% (30).

Effects of CAL in academic education

Learning

Several studies have shown that groups of students who are using CAL have better results than groups using traditional learning (8, 9, 14, 24, 31). Some studies even demonstrate that students using CAL needed shorter time to reach the learning objectives, achieving better final results then students who did not have access to CAL (14, 32). Generally it seems that the more recent a study is, the better are its results. References from the 80s show that CAL is as good as traditional education (16, 33), while later references indicate that CAL is better than traditional education (8, 14, 16, 24, 31, 33–36,). This could reflect the fact that computers have lately become better in graphics, usability, multimedia etc. However, Clark reports that there are biases in many technology-focused papers. Even those with poor controls show the computer to be superior to traditional teaching (37).

An interesting finding is that students with learning difficulties sometimes significantly improve their learning using CAL compared to stronger students. By using CAL the former catch up with the latter (10). The communication between students and teachers generally increases (36), which may provide more shy students with a better chance to verbalise their thoughts. Those students who have used computers in their education seem to be more active and focused than those who have only been exposed to traditional education (31). Other studies demonstrate similar results. Kulik et al. (1991) carried out a meta-analysis of 254 controlled studies, finding that CAL usually had a positive effect on students. Their scores increased by an average of 0.30 standard deviations, which was coupled with a small but positive change in students' attitudes and a substantial reduction in the amount of time required for instruction. The authors indicate that they consider this effect to be significant (38).

Jelovsek et al. (39) examined 49 ''clinical'' trials comparing CAL with conventional methods of learning. The authors focused on studying cognitive outcome, behaviour and learning theory, using students, doctors and patients as learners. The results were:

- In performance terms, CAL was as good as conventional learning in 98% of the trials.
- CAL showed an improvement between pre-test and post-test scores over conventional methods in 61% of the studies.
- Generally learners with CAL took about the same amount of time to achieve a better overall performance, though a small number of studies indicated that more time was taken to achieve a better performance (because of motivation).
- CAL required much less time to achieve the same performance.

Examination

Only a few studies have been carried out in the field of computer-assisted test/examination (CAT) in the field of health science.

One study regarding time-consumption in examination using computers showed that CAT required the same amount of time as traditional multiple-choice examination (14). Studies from other academic fields present similar results (40). Even those students who didn't have any computer experience preferred CAT to traditional paper and pen tests (40). Yet some psychological tests and exams show that CAT can have negative effects on the results of those not familiar with computers (41).

CAL versus traditional dental education

CAL versus books and lectures

When a case is presented in a book, all the learning material is presented linearly, frequently together with a subsequent solution to the case. Often the book begins from an already given topic with a description of a patient record and status for the cases. This principle is also frequently used in lectures: usually the student gets the solution without any interaction with the teacher or content. In CAL the symptoms are presented for a given patient case. The student is put in the role of a professional making a diagnosis for a patient. The student can ask the computer for information relevant to the case. The student suggests a diagnosis/treatment and the computer indicates how well the student has solved the task. Student comments on the chosen selection can be put into a database containing the patient records.

Traditional book and lecture teaching represents a one-way communication with the student. Neither of these resources often stimulates the student. This implies that there is limited possibility for interaction with the resources. CAL, on the other hand, stimulates the student to interactive learning by providing the possibility for interaction with the media, at a personally chosen level. For instance, many of the programs often demand that the student ask for relevant information about the current situation in order to be able to continue. CAL also provides the student with the opportunity to go through the material at his own pace and repeat chosen parts, without involving a teacher or other students. CAL is especially valuable when the program contains possibilities of direct contact with on-site teachers.

The students' learning style

Students want to achieve as good assessments and grades as possible. Because of this, students are usually strategic and use different kinds of learning approaches to different courses, often in sophisticated ways. One important factor is the design of the exam. Depending on the examination form, students employ different learning styles (42). Additionally, when the time for examination is approaching, students often pass from a deeper understanding of the content to a pure memorising mode (43).

Students' learning strategies are often content-dependent (44). There is sometimes a strong correlation between the quantity of necessary activity and the quality of learning. The more that is demanded from students, the more likely they will adapt a superficial learning style (45). In a study done on Nordic dental faculties, many students (54%–77%) thought they had little time available for studying. The students also considered that the teachers had deficient teaching skills. Many students felt that teaching was a second priority for the teachers (46). One reason for negative student attitudes is that sometimes the teaching staff in universities have had limited pedagogic education.

Students usually wish for more factual and concrete information, a more structured curriculum and organised conditions (42, 43). In other words, things should not be left to chance. One of the most popular learning resources is teacher handouts (33, 43). Even small changes in how the information is presented can lead to major alterations in learning outcomes (47).

The computer's teaching style

Research results show that if an image is initially blurry, and then becomes clear, it is remembered much better than if it is presented clearly for the same amount of time. This could mean that if an image were to be drawn instead of being instantly presented, learners might remember it better. It has also been shown that learners have an ability to remember animations well (47). Interactive multimedia software engages students in decision-making and multi-sensory learning. When all senses are stimulated, learning will be most effective and the student more interested (9). It has even been shown that if the computer grants the student an award (e.g. in form of an animated writing of his name), the student will try to perform better (47).

A book can never provide or teach active dental therapy planning. To facilitate this kind of learning, real patients and training are required. A computer can, in a very realistic way, simulate real patients. To be able to go farther in a patient simulation program, the student has to ask for relevant information about the case. This demands that the student be attentive and concentrate, which provides conditions for good learning (47).

Students willingly use sophisticated instruments for learning (8). In addition, if they participate in the development of the software, they will become more motivated to use it (4). Software that is developed by the faculty contains structured, actual and concrete information and is more likely to contain exam-relevant material. Since students adapt a learning style which favours the exam results when practising cases, they will be more motivated to use this software (42, 43, 47). The software is designed in a way that "forces" the student to think and concentrate toward the faculty learning objectives, thus stimulating deeper thinking.

Other advantages of CAL:

- The computer is very patient and has time.
- The computer is not judgmental if the student makes a mistake. The student "dares to answer" the computer's question without risking feeling stupid if he provides the wrong answers.
- CAL can be repeated frequently without the computer "getting tired" or impatient.

Future trends

Learning

The production of CAL packages in dentistry has increased remarkably during the last 5 years. As new authoring tools became available at a low cost, an increasing number of institutions and individuals are now involved in design and production of CAL applications. This has increased both the variety and the quality of CAL applications, while at the same time lowering all costs related to production and use. The Internet can now serve as a universal database of CAL, which is available to a global audience, in many cases free of charge. It is interesting to note that 50% of British dentists would be willing to pay £50 for a CAL package in 1993, while this percentage was lowered to 37% in 1995 and only 5% in 1998 (30). This clearly demonstrates the effects of the Internet and the wide variety of choice that the CAL user has today. In the near future, dentists and dental students will have access to an enormous number of applications, which will also push the quality criteria and demands of the users even further. The only visible obstacles to utilising this media will be the still insufficient computer skills of students and professionals and the lack of research evidence concerning several methodological implications of CAL.

Apart from purely educational applications, computers have been used in several other areas of dental care. Digital image management, for example, in orthodontic KEF calculations and digital X-rays represent some very important applications of computers in Orthodontics. In addition, the CAD/CAM technique is widely applied in restorative dentistry (23). If these resources were connected to a database containing all pre- and post-treatment images, information, and results, a large knowledge-bank would be created. From this, different treatments could be evaluated.

ICT would be of a great help for patients, not only directly, but also by providing the clinician with fast access to updated information which could later be used as a support for clinical decision-making (34).

In preclinical teaching, virtual reality and force-feedback technology will make it possible to simulate

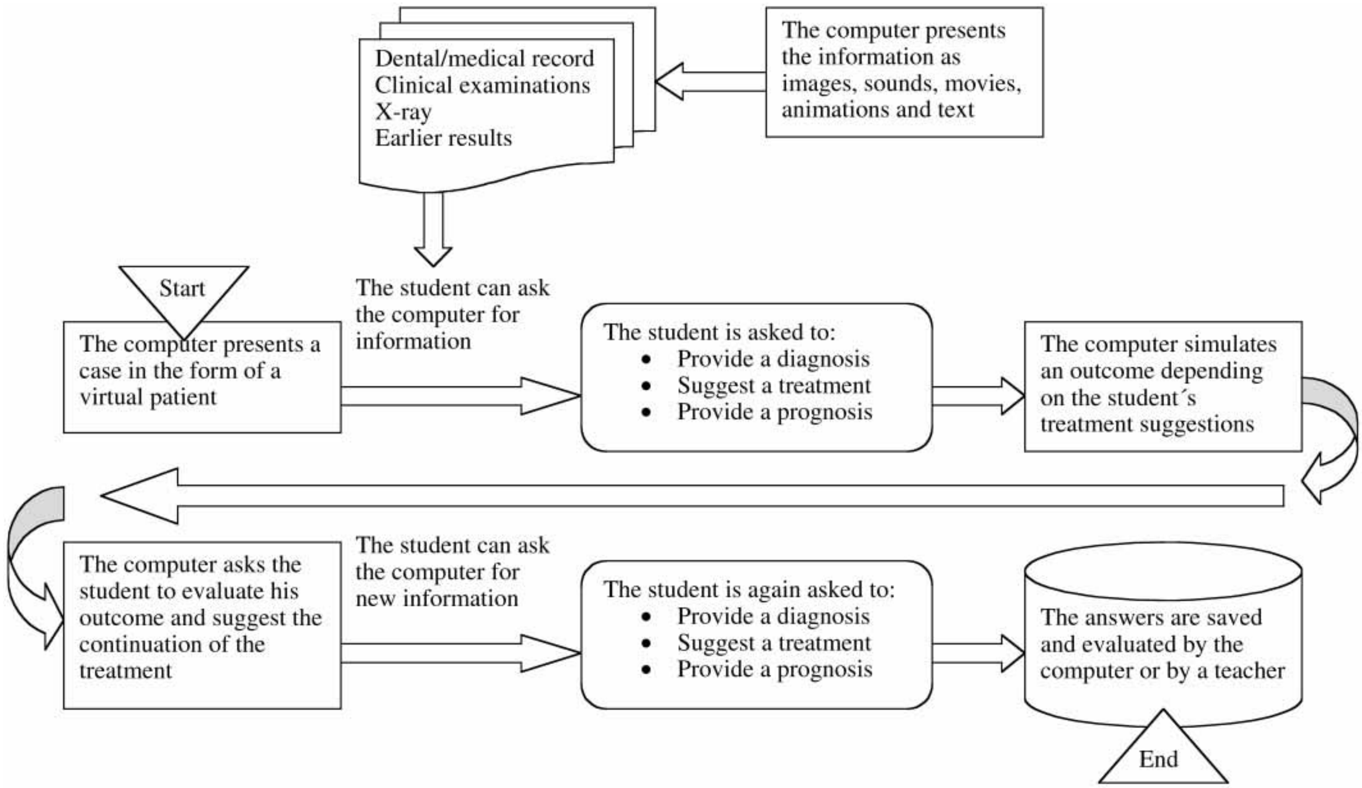

Fig. 1. Graphic illustration of the process when using computer assisted examination procedures in treatment planning

and practise clinical situations in a realistic way without the need of real teeth or expensive plastic ones. The computer may help the student by guiding him/her in clinical procedures. The building of fast network connections will enhance the possibility of providing the learner with high quality images and updated information.

Examination

As in CAL, the computer-mediated test could put the student in the role of a diagnosing professional. The computer presents a short case to the student and asks him to collect essential facts (history, status, x-rays etc). Based on the information available, the student is asked to provide a diagnosis, suggest a treatment and provide a prognosis. The computer simulates an outcome depending on the student's treatment suggestions. The student can then ask for additional facts, if necessary, and then try to request the appropriate treatment alternative. (See Fig. 1).

The concept of virtual patients in Computer Assisted Virtual Examination (CAVE) is not new but was mentioned in 1990 as a potential possibility (48). The advantages of CAVE would be:

- Moving pictures (showing mobility, lower jaw movement, swallowing pattern)
- Sound (TMJ-sound, percussion)
- High quality images (no cost for printing)
- Immediate results
- Time measuring (How much time does a student devote to different questions? Can he better use his time?)
- In case of a wrong answer, the student can be given a second chance (is the student on the correct track) (48).

The exam can be given any time, place, or in privacy without the faculty member present.

Conclusion

Computers are common in dental clinics and processor-based equipment is used in dental therapy. The use of computers cannot be optimised until education in computer skills is included in the undergraduate courses. Computer education should therefore be mandatory in the dental curriculum. Also, it is important that teachers provide role models for students. In addition, the resource persons should be well acquainted with the use of high-quality educational programs based on CAL. Some authors suggest that students will even choose dental schools depending on the extent to which access to CAL is provided.

TABLE 1. Summarising advantages and disadvantages of CAL from the literature

Advantages	Disadvantages
• The student can choose his own way 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 judgmental. The student can learn from his mistakes without embarrassment. • Saves time for the teacher (in the long term). (23, 34) • The students are more activated. (16, 36) • Weak students are favoured. (15, 34)	• Starting costs are high. • The staff needs to be trained. • Students have to be familiarised with the medium. (34, 36)

The use of CAL may enhance education and provide learning opportunities that cannot be taught by traditional strategies. The reported advantages and disadvantages of CAL are presented in Table 1. Research-based development of the learning modules that are especially suitable for CAL would increase its potential. CAL may provide the student with an enhanced everyday decision-making tool in clinical treatment situations. At present, CAL in academic learning should be used as a supplement to traditional education.

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