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Original Research

Can e-learning impart medical students with complex knowledge? A randomized controlled trial

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ABSTRACT

E-learning is a promising educational tool that is rapidly increasing in complexity and contents. While e-learning has proved more effective than no intervention and as effective as classroom teaching methods, little is known about its value in relaying contents of different levels of complexity to students. We wanted to compare knowledge test results after the use of e-cases with textbook learning and case-based classroom teaching for simple recall and complex problem-solving. After a general two-day introduction to emergency room topics, 60 medical students were evenly randomized to two groups and given internetbased knowledge tests before and after head trauma teaching (correct answers from 15 randomly chosen questions from a pool of 30 questions). The Glascow Coma Scale was used for simple recall, and scenarios for emergency room head trauma were used for complex problem-solving. Time spent on educational material was measured. For simple recall, all methods were equally effective. For problem-solving, the eCases group achieved a comparable knowledge level to case-based classroom teaching, while textbook learning was inferior to both ($p<0.01$). The textbook group also spent the least amount of time on acquiring knowledge (18 minutes, $p<0.001$), while the eCases group spent marginally more time on the subject (39 minutes vs 30 minutes, $p=0.06$). eCases are an effective tool for imparting problem-solving ability to medical students, and future studies using higher-level e-learning are encouraged. Simple recall skills, however, do not require any particular learning method.

INTRODUCTION

E-learning may broadly be defined as a learning method employing electronic media and technology with or without the physical presence of a classroom and a teacher and includes a wide range of learning platforms such as the internet, computer programs and multimedia content by other digital delivery methods. Since many examples of e-learning discard the physical interaction between student and teacher, e-learning requires a basic knowledge on behalf of both the teacher and the student of the technology used for accessing these multimedia interfaces, a commitment to carry out the full learning module by the student alone, and a method of controlling the learning process for the teacher. Historically, many learning methods have been used, but in recent years e-learning has been increasingly integrated into medical education with the expansion and dissemination of digital platforms for everyday use [1]. These educational applications are being developed for both pre- and postgraduate training (examples are: eFront, Moodle, Dokeos, Claroline, Ilias etc.) and used at Universities as part of their curriculum. As previously mentioned, e-learning differs from former educational methods in the shift from teaching to learning, in which the student is required to actively search knowledge instead of being a passive recipient of such [2].

A major issue when discussing the value of e-learning is the potential difference in material quality, communication skills and digital setup, making comparisons between learning methods uneven and hard to quantify. The highly variable description methodology used when describing e-learning means that the reliability of data regarding the efficacy of e-learning on both direct and long-term effects may be misleading. The quality of many studies is also variable, with a control group either lacking or not well defined [3].

Given these caveats, studies show that e-learning is significantly better on several success parameters than no educational method at all, but that it is often similar in quality to traditional classroom teaching [3]. These broad outlines of results, however, do not adequately reflect the true place of e-learning within the spectrum of medical learning methods since the nature of the learning material may be widely different between studies. For example, it is unclear whether e-learning is better applied to recall of simple educational points than to the application and analysis of the complex scenarios of medical patients. A systematic description of e-learning content is very much needed, but formerly used scales are becoming insufficient with the advent of recent technological developments [1,4-6]. We suggest a new taxonomy where we divide e-learning into tree different *types* and three different *levels*. *Type* corresponds to the learning method and are divided into 1.Presentations (simple e-learning with no interactivity), 2. Scenarios (simple interactions fx cases that allow the learner to take decisions) or 3. Games/simulations (complex computer based patient scenarios with multiple students interacting). *Level* refers to the multimedia development level. Multimedia *level 1* includes text, basic images, audio, simple interactivities for content presentation and a template layout used trough all e-learning pages. *Level 2* adds video, simple animations and variations on the presented e-learning pages. *Level 3 have* complex animation, high fidelity/3D graphics, complex multilevel and multivariable interaction. Studies in e-learning materials may thus be divided into nine different categories. Furthermore, non-e-learning methods may also be divided into the same three *types* of teaching (presentations, scenarios, and simulations). Learning objectives include recall, analysis and problem solving, each of which may be achieved to different degrees for each learning type and level [7-10].

The use of cased-based teaching in medical education was already in use in 1788 at the Medical Society of New Haven and now used at most universities. Cook concluded in his review about computerized virtual patients [11] that cases in computerized medical education was comparable to noncomputer interventions, but did not distinguish between simple and complex knowledge.

Aim of the study

A) Type of learning. Since previous studies have compared mixed *levels* of learning methods or did not use relevant control groups, our aim was to compare two different *types* of e-learning with traditional scenario-based teaching of the same *type* of learning, We did not use video or animations, and all pages were standard view. This kind of teaching is often used when addressing senior medical students in Denmark. The reasoning was that if simple level-1 e-learning is valuable compared to classroom learning, then higher levels would be at least as good, if not better.

B) Simple or complex knowledge. We also wanted to test learning ability of simple or complex learning content in the different groups. The learning objective of simple content included recall of the elements of the Glascow Coma Scale [12], while the learning objective of complex content included analysis and application of knowledge to head trauma scenarios with the potential for complex physiological interactions and multi-organ involvement.

MATERIAL AND METHODS

*Learning courses and groups.*Test subjects were Danish medical students in fourth to fifth year of training who were preparing to work either as doctors or students in Danish emergency departments. A basic educational course (from the Association of Danish Medical Students) was repeated four times with 15 students participating in each course. The students had a possibility to participate in an add-on course regarding head injury and all students did.

Before starting this course, students were given two weeks to take a pre-test of basic points that were to be included in the course itself. No students were admitted to the course without prior completion of the pretest, but the result of the pre-test did not influence participation in the course. The course lasted two days with a total of 8 hours of theoretical case-based teaching. The contents of this teaching module primarily dealt with general emergency room issues, none of which included GCS scoring. None of the students had prior experience with ER work. After completing this basic course, students were randomly divided into three equal numbered groups using computer block randomization. Group 1 (eCases, n=20) participated in an interactive case-based e-learning program, while group 2 (eTextbook, n=20) were presented with textbook material electronically. Group 3 (case-based classroom teaching, n=20) received case-based classroom education. The contents of this part of the program was head injury and the associated treatment and observation guidelines in the emergency room. This part of the education was in Group 1 and 3 based on two case-stories and description of one procedural skill, namely the GCS score. Groups 1 and 2 were free to use their e-learning module as much as they desired. All students were then required to deliver a post-test within one week. The improvement of each participant (post-test result minus pre-test result) was used as statistic for comparison between groups. The amount of time that each student spent of each educational element was also measured.

*Module setup.*The pre-test, post-test, questionnaire and e-learning modules were all designed using Moodle - a free, open-source PHP web application for producing modular internet-based courses (also used on many universities – Minnesota, Cambridge, Oxford, Edinburgh, Washington, York etc.) integrated into www.medviden.dk, a free Danish homepage for medical education. All parts of the study were closed and required password for admittance, but in the future the e-learning modules will be opened for free access. The program was carried out in Danish.

*Pre- and post-tests.*Pre- and post-tests both consisted of 15 questions randomly chosen from a pool of 30 different questions. In order to avoid confounding, the questions were shuffled for every course. The questions were provided in several formats including multiple choice (single best answer from multiple answers) and true/false questions. The questions included clinical photos, and both tests were based on true clinical stories. The questions were all used in former examinations at fifth or sixth years at Copenhagen University Faculty of Medicine thereby also verified by leading physicians. Both tests were online reviewed (pilot-tested) and validated by two senior doctors working with extensive experience in emergency medicine in Denmark securing the clinical relevance. The questions was divided into simple or complex knowledge requirement. The questions were rated as being of equivalent difficulty and of similar clinical relevance, and they ensured that the material covered by the tests was addressed by both the e-learning modules and the keynote presentation. Both tests were produced after the learning material in order to avoid the risk of teaching to the tests. The students had a time limit of 30 minutes for completion of each test. Only one correct answer was permitted for each question.

eCases (group 1). The eCases module was prepared using clinical cases, pictures and explanations. The same keynote presentation used in Group 3 was uploaded, and the students had the possibility to read the slides more than once. Two case-stories were presented, and the student was able to follow more than one path toward the conclusion of the case. Both cases were based on clinical stories and used images, illustrations and clinical data from relevant cases. The path trough the case-stories depended on the students' choices and interaction and they always had a possibility to activate a help function directing them to read about the relevant topic. Both stories started at arrival in the ER and depending on their choices the patient reacted with different outcome (e.g. it the student did not order a CT-scan – none were presented). The cases were not depending on how much time was used on each stage. After each case the most appropriate path was shown. We did not want to create a bias regarding questioning, and therefore we did not use questions within the e-learning modules.

eTextbook (group 2). The eTextbook was an ordinary homepage presenting textbook material electronically, excluding clinical cases, pictures or explanations. We did not want to create a bias regarding questioning, and therefore we did not use questions within the eTextbook modules.

*Case-based classroom teaching (group 3).*The case-based group was presented with a keynote classroom lecture and didactic teaching about the subject. The same two case-stories as in group 1 were presented. First the students worked individually with the cases and afterwards they were discussed within the group. Only the most appropriate decisions were allowed. All students were instructed in the use of the GCS score. The teacher was available for questioning.

*Questionnaire.*All participants were asked to complete a questionnaire after completing the post-test. The questionnaire obtained general feedback regarding the educational method. A PDF version of the questionnaire is available [in Danish] upon request.

Study size and statistical tests. Deriving experiences from a pilot study, the post-test-pre-test difference of positive answers in group 2 (eTextbook) was anticipated to be 30% (an improvement in correct answers from 30% to 60%). Anticipated range for this difference would be 20-40%, thereby applying a standard deviation for all groups at 5%. Our anticipation was that all educational methods would only deviate slightly from each other, and a 5% difference was chosen as a MIREDIF. Significance level was set at 5%, and statistical power at 80%. This yielded a total of 16 subjects in each group [http://www.opengcp.dk/calmiredif.php]. To avoid an impact due to dropouts or missing data, it was decided that each group consisted of 20 subjects. Posttest-pretest difference for each participant was chosen as our primary statistic. Given the limited number of participants, the Mann-Whitney U-test was chosen for between-group comparisons.

Ethics

The study was purely educational and the Danish National Committee on Health Research Ethics (DNVK), Regional Region was consulted. Their conclusion was that study did not require ethical approval (h-4-2013-fsp 41).

RESULTS

All 60 students concluded both pre- and post-tests and the educational elements of the study. Pre-test and post-test results are presented in figure 1, with between-group comparisons in Figure 2 and 3. The three groups have comparable pre-test results (Figure 1).

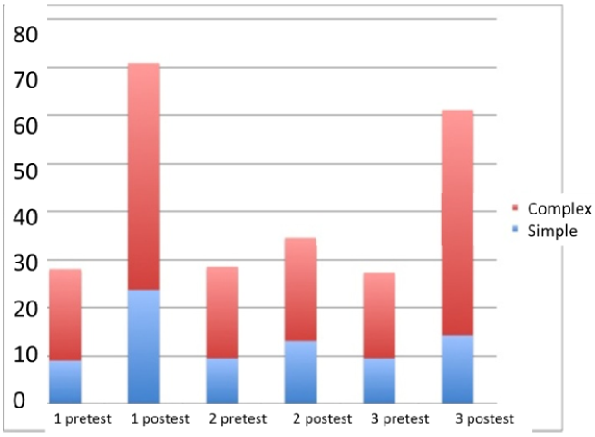

Figure 1. Correct answers in pre-tests and post-tests.

Legend: Values are relative numbers of correct answers for each type of educational content in each group. N=20 in each group.

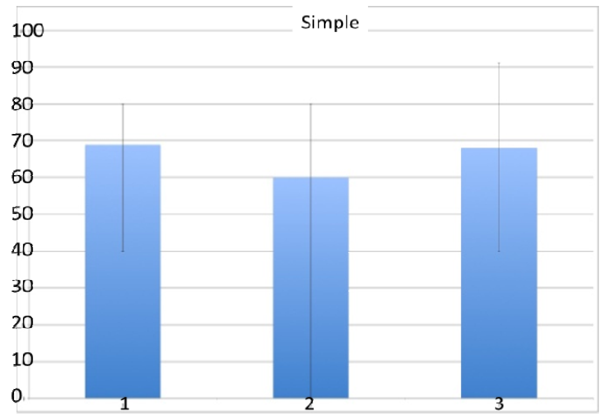

Figure 2. Between-group comparisons in test result improvements, simple knowledge in percent.

Legend: Mann-Whitney U-test for all comparisons. Group 1 vs group 2 P = 0.37, Group 1 vs group 3 P =0.78, Group 2 vs group 3 P = 0.31. N=20 in each group.

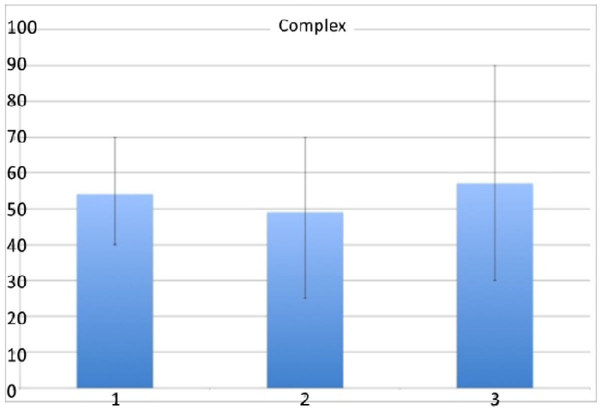

Figure 3. Between-group comparisons in test result improvements, complex scenarios in percent.

Legend: Mann-Whitney U-test for all comparisons. Group 1 vs group 2 P >0.001, Group 1 vs group 3 P =0.48, Group 2 vs group 3 P >0.001. N=20 in each group.

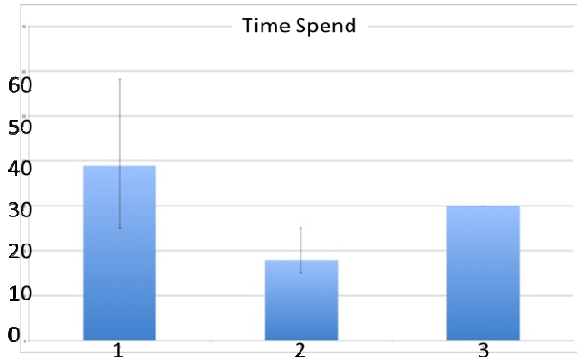

Figure 4. Average time spent on educational material by students in each group, for simple and complex problems combined.

Legend: Time spent in minutes, with 95% confidence interval in error bars. Mann-Whitney U-test for all comparisons. Group 1 vs group 2 P >0.001, Group 1 vs group 3 P =0.06, Group 2 vs group 3 P >0.001. N=20 in each group.

For recall of simple knowledge (the GCS score), all educational methods were equally successful in improving the knowledge of the students (Figure 2). For analysis of complex scenarios (emergency room head trauma cases), the group given textbook material (group 2) acquired significantly less improvement than either of the other two groups (eCases or case-based learning) (Figure 3). Time spent with educational material was significantly less in the textbook group ($p<0.001$) and marginally more in the eCases group compared to the case-based learning group ($p=0.06$, Figure 4).

DISCUSSION

Benefit of learning methods. All students achieved improvements in their post-test scores compared to the pre-test scores. The degree of improvement was of a similar magnitude in the recall of simple knowledge than for analysis of complex scenarios. We conclude that the recall of simple knowledge does not seem to be dependent on the learning method, while analysis and problem-solving other hand seems dependent on a case-based method, which may be implemented equally well by eCases or case-based classroom teaching. Case-based teaching achieves the same good results as eCases but with less time spent on the educational process for each student. Also, it is particularly noteworthy that students spent less time delving on the eTextbooks, which generated the poorest result for the complex scenarios, suggesting that the students either overestimated the breadth of the knowledge they attained from the eTextbook, or that the eTextbook itself had limitations in its ability to transform its straightforward theoretical text into complex problem-solving in real-life settings.

The difference between simple and complex knowledge gain could be that simple knowledge only need surface-learning while complex knowledge need deep-learning. This deep learning is exactly what the teaching material, type and method should support. A lot is known about experts' case-solving (knowledge structures and thinking strategies) and in order to become an expert intensive training are required. Students need to develop a highly organized knowledge structure in order to use pattern recognition. Physicians acquire a body of knowledge over many years and the pattern recognition is only doable because of their experience [13]. Electronic cases could be a way of teaching experience without patient interaction. This could also be the reason why both groups taught with cases are equal.

The overall value of case-based teaching methods may first be fully appreciated when viewed in a broader frame: classical teaching requires the logistical setup of placing students and teacher in the same location at the same time, while the eCases setup does not; eCases, however, require considerable semi-interactive computer programming skill on behalf of the teacher and resources dedicated to this purpose, some of which may overshadow their logistical advantages.

A potential limitation to our study is the theoretical risk of teaching-to-the-test bias, especially in group 3 (case-based classroom teaching), but we believe this bias has been reduced by the creation of the tests *after* creating teaching materials; in addition, the direction of such a potential bias would reduce the improvements seen after case-based learning, thus making eCases the superior method. Nevertheless, we can confirm that case-based learning methods are superior for imparting students with problem-solving ability, and that eCases may, at the very least, be as competent a method as the classic, case-based learning methods of the classroom [7].

Educational methods, learning levels and resources. It is important to choose the right educational method to the content and purpose of the educational material. E-learning has some benefits while traditional teaching has others. Most e-learning platforms are not yet ready to facilitate learning the way traditional teaching does when addressing the social aspect and the benefits of live classroom interaction [5, 6]. E-learning has potential advantages over didactic learning, both when looking at accessibility and advanced contents (multimedia and interactive navigation). This study has investigated simple e-learning tools, but we hypothesize that higher-level e-learning may lead to competitions and direct student interactions which may eventually resemble those seen in classroom settings [1]. At the end of the day, however, it may all come down to cost-benefit analyses. How are we able to create the best learning environment with the least resources? When the overall conclusion is that e-learning is as good as traditional teaching, this could be an essential argument for such a way of thinking [14]. Our study does not compare development costs versus learning potential, but we theorize that higher levels and types of e-learning would be more expensive than both didactic teaching and lower-level e-learning. In addition, we are still unable to judge if there are major benefits for higher-level e-learning compared to lower-level e-learning, or which levels of e-learning may adequately improve higher-order skills such as cognitive abilities in the students [15].

*Future medical education.*Wutoh concluded in his review from 2004 that there is no significant difference between e-learning and didactic medical teaching [16]. In the years since that review, the dramatic developments in e-learning contents and levels would suggest an even better effect. In other words, e-learning is at least as effective as traditional learning even when teaching the use of complex problem-solving. Other skills are of course important, since good doctors require a combination of skills, such as readily available knowledge, manual dexterity, clinical experience and cognitive abilities. Although some authors have tried, the educational need of this palette of skills may currently be difficult to satisfy with e-learning alone, but future technological developments catering to such complex skill sets may not be far off with the increasing use of computer games, virtual reality simulations and social networks [15].

CONCLUSIONS

The results of this study are encouraging. E-learning does in fact work as well as classic teaching of the same type, and e-learning with cases works significantly better than e-learning with only textbook material. Following this path and evaluating whether different levels of e-learning could in fact provide better results may be the next logical step of inquiry. At least we hope that the variable description methodology formerly used can be standardized, and that future studies compare e-learning with the same type of classic teaching and with the same contents and complexity.

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