Introducing e-learning/teaching in a physiology course for medical students: acceptance by students and subjective effect on learning

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Submitted 27 November 2012; accepted in final form 6 August 2013

Felder E, Fauler M, Geiler S. Introducing e-learning/teaching in a physiology course for medical students: acceptance by students and subjective effect on learning. Adv Physiol Educ 37: 337–342, 2013; doi:10.1152/advan.00158.2012.—Retrieval of information has substantially changed within the last two decades. Naturally, this has also affected learning/teaching techniques, and methods that are commonly referred to as “e-learning” have become an important part in modern education. Institutions have to decide if (and how) to implement this new form of teaching but face the problem that little subject-specific research has been published for different teaching modes and methods. The present study compares a course module of the physiology laboratory course for medical students in the preclinical phase before and after the introduction of computer-aided course instructions (CACI). Students were provided with an online questionnaire containing Likert items evaluating workspace redesign, acceptance of course instructions, incentive to actively participate in the course, and subjective gain of knowledge. CACI was clearly preferred over the previously used paper workbook. However, the questionnaire also revealed that the gain in knowledge, as subjectively perceived by the students, had not improved, which is in agreement with several studies that neglected a beneficial effect of e-learning on learning success. We conclude that the CACI meet today’s student’s expectations and that introducing this system seems justified from this perspective.

e-learning; hearing; Lab Tutor; physiology course

The scientific achievements of the last decades have revolutionized our view of diseases, their cause, and how they can be treated. At the same time, the way that information is retrieved has dramatically changed. Faculty and staff at universities, and, to an even greater extent, also decision makers in higher education experience learning completely differently than the current body of students (19). The majority of print journals have been replaced by electronic versions (5, 6, 8) and libraries steadily increase access to e-books (10, 16, 24). Despite initial doubts (12) in how far “computer-assisted instruction” would change medical education, university teachers should be aware that students nowadays might consider conventional paper portfolios inadequate. Several studies (1, 9, 13, 21, 22) have demonstrated a high acceptance of various kinds of e-learning by learners. Other studies (20, 25) have shown the beneficial effects of various different forms of e-learning, and when learning success is compared, e-learning is at least as effective as conventional learning methods (2, 9, 15, 18, 22). The interactive nature of e-learning, and the ability to conveniently structure teaching objectives, allows cross-references (links) to other topics. The easy integration of graphic information makes e-learning a practical tool to guide students through complex procedural processes, e.g., laboratory experiments. For some forms of education, e-learning might effectively support peer-assisted learning or even entirely substitute for it.

In our study, we evaluated one module of a mandatory physiology laboratory course that is part of the preclinical phase in medical education at the University of Ulm (Ulm, Germany). We compared the module before and after implementation of computer-aided course instructions (CACI). The implementation also included a redesign of the workspace to meet the technical requirements for this teaching method (monitors, computers, etc.). The aim of the study was to determine if the new teaching concept was indeed considered an improvement by the course participants. The results should also assist other institutions in deciding whether that implementation of a CACI system in a practical course is worth the effort and justifies the costs.

Materials and Methods

Description of the participants. The laboratory course in physiology at the University of Ulm is compulsory for medical students of the third preclinical semester in medicine. Students were only admitted to the course if they had successfully passed the exams in histology, physics, and biology held in the previous two semesters. In the second semester, students listened to an introductory physiology lecture that provided background information for the course.

General layout of the physiology course. The course is composed of nine different modules with independent topics and deepens the knowledge of the main physiology lectures held in the previous semester. Groups of 16 students perform practical exercises (laboratory exercises or other experiments) and then analyze and interpret the acquired data within a scheduled time range of 5 h. The subject of this investigation was a practical module called “Hearing” that is divided into four subsections (audiometry, otoacoustic emissions, directional hearing, and experiments with tuning forks), each accommodating one subgroup of four students at a time. Subgroups rotate between the subsections until each group has completed the entire module.

In both teaching systems [paper workbook (WB) and CACI], students were assisted by student tutors (usually fifth- to seventh-semester medicine) during the course.

Changes of the work space design to accommodate CACI. When the WB was used, the four subsections were separated by moveable wooden dividers to ensure an undisturbed working environment for each subgroup. Each subsection was equipped with all experimental devices, and chairs were arranged around the table of the subsection. As tutoring via the CACI system depended on reading the instructions from computer monitors, the workspace for each individual subsection underwent a considerable redesign to accommodate the monitors as well as the computers and keyboards. For that purpose, acoustic
booths were designed and built by the university workshop (Fig. 1, A and B). Multiple monitors could be mounted on each booth so that all students of a subgroup could follow the instruction of the electronic tutor during the ongoing experiment. On a second monitor, the software for the experiments was shown (see the example of subsection “otoacoustic emissions” in Fig. 1, B and C). The computers were conveniently stored on top of the booths. The booths were wide enough to fit two students in the first row to operate the CACI and devices to perform the experiments. The two remaining students in the back row could follow the experiment on the overhead monitors attached to the head panel of each booth. Similar to the wooden walls we used for the WB, the booths also functioned as room dividers to separate the different subgroups from each other.

Comparison of WB and CACI tutoring systems. The two systems (WB or CACI) were evaluated by analyzing student questionnaires from 2 consecutive years. In the first year, the WB was used, whereas in the following year, the CACI system was used.

The WB was a printed course guide with a total length of 11 pages. Each student used his/her own printout during the course to obtain background information and instructions. Moreover, the WB was used to record the results of the experiments and exercises (see also below). The CACI system was based on the commercially available Lab Tutor Teaching Suite software package (version 4.1, AD Instruments). The graphical user interface uses a conventional Web browser and is compiled by special authoring software. It allows data readouts from measurement devices, manual data input, and data analysis as well as a presentation of the results or instructions as graphs or diagrams. We used Lab Tutor exclusively for instructions and manual data input including the presentation of results as graphs. Students accessed the CACI pages from dedicated computers at each subsection. After logging in with their subgroup account (comprising 4 students) at a particular subsection, the students chose the respective subsections at the CACI page to begin.

In both systems, students could access the course material weeks before the beginning of the course: the WB was available as a .pdf file on the educational server for download and the CACI webpages were accessible via the internet from external computers using the subgroup account that was provided by the department before the course.

The WB provided a summary of the required background knowledge as well as an overview of how to perform the experiments. The text was supported by explanatory illustrations. For affordable printouts, the figures were created in black and white.

Similar to the WB, the CACI system first provided background knowledge. However, the better graphic possibilities and lack of need to print costly color figures allowed us to implement more graphic elements in the CACI compared with the WB. In both systems, contiguity as well as cueing principles were used for the figures.

In the WB system, additional information, especially regarding experimental procedures and details about devices, was presented on posters. The posters were placed close to each subsection in sight of all students. In contrast, the CACI included these operating instructions (devices, etc.) to provide a detailed step-by-step description to guide students through the experiments (“stand-alone manual”).

In the WB as well as in the CACI system, students were required to document the results of (most) experiments in designated areas of the WB or CACI page, usually by filling out tables or by drawing diagrams. Moreover, written answers had to be given to questions, which encouraged the students to explain results and put them in the right context. The content of these tasks/questions was practically identical in both systems. Naturally, the WB required handwriting, whereas data were entered via a keyboard in the CACI system. A big difference between the two systems was the mode of data analysis. Graphs had to be drawn by hand, whereas with the CACI, the numeric data were automatically converted into graphs, and students could immediately compare data of new experimental conditions with already existing data sets. In contrast to the WB, the CACI documented student responses in a separate report page, where all answers, graphs, and other experimental data could be accessed and reviewed. The report page contained a brief description of each data set or the related question. In both systems, the protocol was available for students after the course. The WB remained in possession of the student, and the CACI pages, including the completed report page, could be viewed online later during the entire semester through Lab Tutor. In addition, the protocol page could be printed after the course.

All students of a subgroup used the same CACI login account in each subsection, whereas one printed WB per student was used. Hence, the CACI system forced all members of a subgroup to follow the instructions together and perform the experiments as a group. Questions and data input had to be dealt with simultaneously. Problems in understanding the purpose of the experiment or how to perform the experiments were encountered by all students of a subgroup at the same time, and students were required to reach a consensus on their answers. This is a marked difference to the WB, where students had more opportunities to detach from the rest of the group using their individual printouts of the WB. We expected the synchronized work flow with the CACI to affect students’ interactions and their motivation to discuss within the subgroup and review course instructions and objectives in the group. Taken together, this also might have an effect on the incentive to actively participate in experiments.

Fig. 1. Redesign of the course module “Hearing” and workspace redesign to implement the computer-aided course instructions (CACI). A: the four subsections of the module (see labels) were distributed in four acoustic booths. The booths were lined with a sound-absorbing material, and each booth accommodated four students. B: monitors inside the booth and overhead monitors allowed all students of a subgroup to follow the experiments and CACI. C: example how the software for the experiments and CACI were used simultaneously. The CACI provided background information as well as instructions on how to operate the software for the experiments or advice on how to perform the experiments.
Advances in Physiology Education • doi:10.1152/advan.00158.2012 • http://advan.physiology.org

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Fig. 2. Evaluation of the workspace in general. All statements regarding the overall acceptance of the new design were significantly better rated when the CACI was used. The wording of the entire statements is given in the RESULTS. WB, paper workbook.

Data collection and analysis. To qualitatively assess the differences between the two systems, course participants were requested to answer a close-ended questionnaire. The questionnaire contained 13 Likert items (for wording, see the RESULTS) to evaluate different aspects of teaching methods. Items 1 and 2 (Fig. 2) referred to the redesign of the laboratory room. To evaluate how the WB and CACI were perceived by the students, we formulated items 3–6 (Fig. 3). Items 7 and 8 (Fig. 3) compared student perceptions of guidance through the course and the mode of protocoling. The relative motivation of the students between the two different systems was assessed by Likert items 9–11 (Fig. 4), and, finally, students were questioned how they judge their subjective gain in knowledge (items 12 and 13). Each Likert item was rated on a six-point scale (where 1 = definitely not applicable and 6 = absolutely applicable).

Students of 2 course years (one year with the WB and the other year with the CACI) were invited to participate via e-mail after the end of the second course year. The e-mail provided an individual username and password for each student to log into a webpage where the questions were hosted. Login was anonymous, and the questionnaire was answered online by selecting one of the six available grades (see above) for each Likert item. There was no time limit for answering the items. The survey was deployed using EvaSys Education Suite (version 5.1) software. Questions for both groups were identical except that either “WB” or “CACI” for the respective course years was used when required by the question. Ratings were analyzed with IBM SPSS Statistics 20 software. Statistical significance (P values of <0.05 by an unpaired Student’s t-test) is indicated by an asterisk in the figures, and exact P values are presented in the RESULTS.

Moreover, items that belong together according to the description above (workspace design, acceptance, incentive for self/group-driven activities, and subjective gain of knowledge) were summarized to factors by calculating the average values. A Pearson’s correlation of these factors was determined with IBM SPSS 20 software.

Fig. 3. Acceptance of the WB and CACI. Obviously, students preferred the CACI over the WB as all related statements were significantly better rated and clearly favored the CACI. The wording of the entire statements is given in the RESULTS.

RESULTS

The number of students that participated in the survey was 55 students (17.5% of all participants) for winter semester 2010/2011 where the WB was used and 98 students (30.7% of all participants) for the consecutive winter semester in 2011/2012 where the CACI system was used.

Acceptance of the workspace redesign. As shown in Fig. 2, the redesigned workspace separating the course in four subsections by the acoustic booths (see Fig. 1, A and B, photo of the room) was significantly better rated for the CACI. This refers to the following statements: “The overall spatial arrangement is good” (item 1, WB: 3.8 ± 1.4 and CACI: 4.3 ± 1.3, P = 0.04) and “The spatial separation of the subsection is good” (item 2, WB: 4.0 ± 1.5 and CACI: 4.8 ± 1.4, P = 0.04).

Acceptance of the WB and CACI. Six Likert items were created to evaluate how the students perceived the two different course guides. As shown in Fig. 3, the CACI was significantly better evaluated in all related statements, partly with dramatic differences between the two methods. The statements “The information about the background was helpful” (item 3, WB: 3.6 ± 1.4 and CACI: 4.5 ± 1.1, P < 0.001) and “The graphic illustration of background knowledge was well conveyed” (item 4, WB: 3.5 ± 1.2 and CACI: 4.6 ± 1.1, P < 0.001) indicate that the CACI system provided a better presentation of background knowledge. Also, the purpose and description of the experiments were clearly better evaluated, as reflected by the students’ ratings to the statements “The purpose of the

Fig. 4. Student motivation to actively participate in the experiments and discussions. The CACI stimulated discussions between the students slightly more than the WB (P = 0.06) but produced a significantly higher incentive to look into the course objectives. The incentive to actively participate in the course was moderately higher with the CACI (P = 0.08).
experiments was well conveyed” (item 5, WB: 3.9 ± 1.2 and CACI: 4.6 ± 1.0, P < 0.001) and “The graphic illustration of the experiments was good” (item 6, WB: 3.6 ± 1.2 and CACI: 4.9 ± 1.0, P < 0.001).

Students also perceived a significant improvement on how they were guided through the experiments by the CACI system (item 7, “The guidance through the experiments was well done,” WB: 3.7 ± 1.2 and CACI: 4.8 ± 1.1, P < 0.001). Also, the mode of recordkeeping (item 8, “The mode of writing the protocol was practical,” WB: 4.1 ± 1.1 and CACI: 4.8 ± 1.1, P = 0.003) was clearly better rated for the CACI system.

**Incentive for self/group-driven activities.** Figure 4 shows the motivation of the students to actively deal with the contents of the course without specifically being prompted to do so. When the motivation of the students to discuss the purpose and outcome of the experiments was evaluated (item 9, “The design of the course encouraged discussion within subgroups,” WB: 4.4 ± 1.3 and CACI: 4.8 ± 1.1, P = 0.06), the CACI was slightly better rated than the WB, although statistical significance was narrowly missed. However, in both methods, the scores were remarkably high. The rating of the statement “Incentive by the course guide (WB/CACI) to look actively into the objectives of the course is high” (item 10, WB: 3.9 ± 1.2 and CACI: 4.6 ± 1.0, P = 0.03) was significantly higher rated with the CACI. When students were asked to what extent the WB/CACI motivated them to actively participate in the experiments (item 11, “Incentive by the course guide (WB/CACI) to actively participate in the experiments was high,” WB: 4.7 ± 1.3 and CACI: 5.0 ± 1.1, P = 0.08), we found slightly higher values with the CACI.

**Self-assessed gain of knowledge.** When the gain of knowledge as subjectively appraised by the students was compared (Fig. 5), neither of the two course guide systems showed better scores. There were no significant differences between the two systems when the students were asked if their knowledge about the course topic had improved (item 12, “The course helped me to improve my knowledge about the course topic,” WB: 4.5 ± 1.1 and CACI: 4.7 ± 1.1, P = 0.3) or if they better understood the related parts of the physiology content (item 13, “The course helped me to deepen my knowledge of the respective parts in the physiology lecture,” WB: 4.8 ± 1.1 and CACI: 4.7 ± 1.2, P = 0.7).

**Correlation analysis.** For the correlation analysis, we grouped the items of the categories so that one factor comprised all items of one figure. As shown in Table 1, a strong correlation was found between the items of Fig. 3 (acceptance) and Fig. 4 (motivation). These correlations were significant at the 0.01 level.

**DISCUSSION**

In our study, we compared a module of the medical physiology course before and after implementation of an interactive electronic course guide. This included the adaptation of the course rooms to provide more computer workspace and monitors. Students considered the modernization a clear improvement in many regards. However, the survey showed that both systems had the same scores when students subjectively judged their gain in knowledge by participating in the laboratory. The lower response rate of the group using the WB is explained by the delay between the end of the course and when this group was prompted to complete the questionnaire.

The students’ evaluations clearly demonstrate that the new interior fitting of the course room was greatly appreciated compared with the previous course year, where experiments were separated only by wooden walls (Fig. 2). From our own observations, the separation also markedly reduced disturbances between groups from different subsections. Supervising tutors also considered the new workspace design to be clearly more beneficial for performing the experiments.

The scores that describe students’ acceptance for the WB or CACI (Fig. 3) were similar to the workspace redesign, clearly in favor of the CACI. All related statements showed a remarkably higher ranking of the CACI. This included the transfer of background knowledge, the explanation and guidance through

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**Table 1. Correlation analysis**

<table>
<thead>
<tr>
<th></th>
<th>Workspace Design</th>
<th>Acceptance</th>
<th>Incentive for Self/Group-driven Activities</th>
<th>Subjective Gain of Knowledge</th>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Workspace design</td>
<td>1.00</td>
<td>0.268</td>
<td>0.306*</td>
<td>0.415†</td>
</tr>
<tr>
<td>Acceptance</td>
<td></td>
<td>1.000</td>
<td>0.573†</td>
<td>0.245</td>
</tr>
<tr>
<td>Incentive for self/group-driven activities</td>
<td></td>
<td>1.000</td>
<td>0.401†</td>
<td></td>
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<tr>
<td><strong>Computer-aided course instructions</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Workspace design</td>
<td>1.00</td>
<td>0.229*</td>
<td>0.206*</td>
<td>0.184</td>
</tr>
<tr>
<td>Acceptance</td>
<td></td>
<td>1.000</td>
<td>0.564†</td>
<td>0.586†</td>
</tr>
<tr>
<td>Incentive for self/group-driven activities</td>
<td></td>
<td>1.000</td>
<td>0.485†</td>
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</tr>
</tbody>
</table>

The four factors (i.e., workspace design, acceptance, incentive for self/group-driven activities, and subjective gain of knowledge) were grouped so that each factor represents all items of one figure (Figs. 2–5). The level of statistical significance is indicated with * (0.05) or † (0.01).
the experiments, as well as recordkeeping. As mentioned in the Introduction, the higher acceptance of e-learning compared with conventional teaching methods has been described by other authors (1, 9, 13, 21, 22). Hence, the better scores for the CACI were not entirely surprising. Already 10 yr ago, virtually all students in the United States were using computers at the age of 18 yr (14), and, nowadays, Google and Wikipedia are the first point of search for both faculty members and students (7). Therefore, from a student’s point of view, the use of a web-based course guide simply matches their familiar mode of information retrieval.

The biggest difference of the entire survey was found when the graphic representation of information was compared between the CACI and WB. From the teacher’s (creator of the instructions) point of view, the CACI allows much easier implementation of (color) figures and graphs, resulting in a more appealing and more informative graphic layout. The virtually unlimited page length of a CACI page avoids any layout problems related to page length and costs. “Hypertext” links within the document provide an easy way to add figures or background information wherever desired. Obviously this graphic improvement was greatly appreciated by students, which probably also had an impact on the higher acceptance in general. Furthermore, the possibility to include video instructions or other animated material could further improve the effectiveness of knowledge presentation, which would be impossible in a printed WB.

In addition, we were interested in how far the WB or CACI stimulated students to initiate or participate in discussions within the subgroup and to conduct the experiments (Fig. 4). Our study found elevated scores for the CACI in all three categories, although only the incentive to look into the laboratory objective was significantly higher. As students ratings showed such high acceptance for the CACI (see above), and the supervising tutors also noticed a higher interest of the students when they used the CACI, it seemed somewhat surprising that the differences were not stronger. However, in both cases where no significant increase was observed, statistical significance was only narrowly missed. Moreover, in both cases, scores for both the WB and CACI were remarkably high (4.4–4.7 on a graded scale of 6) and, hence, hard to exceed. Motivation (Fig. 4) and acceptance (Fig. 3) were strongly correlated in both the WB and CACI. This underlines how much both factors are interconnected.

Unfortunately, we could not objectively compare the learning success of both course guides in our study. According to the curriculum for physiology at the University of Ulm, the course contents are not tested separately but are part of two comprehensive tests that also include the contents of physiology lectures and seminars. However, we found that the self-assessed gain in knowledge about the topics of the laboratory (or the related part of the main physiology lecture) was not significantly different between the CACI and WB.

There is a lack of consensus in the literature on the effectiveness of e-learning/online learning. A study by Means and colleagues (17) found beneficial effects of e-learning, especially when blended with conventional teaching. In addition, Triola et al. (23) emphasized the advantages of e-learning when the results of various studies were summarized. On the other hand, several studies have found e-learning not to be more effective than conventional learning methods (2, 9, 15, 18, 22), and the outcome of learning seems to depend more strongly on the time on task instead of the method (4). Hence, the lack of subjective knowledge gain is in agreement with these studies that do not report a higher learning success with e-learning.

Several authors have demanded well-grounded and precise studies when evaluating the benefits of e-learning (7) and a study design that is not only based on “compared with an intervention” (3). The present study also had to compromise between the requirements of a course that accommodates 350–400 medical students and ideal experimental conditions with a proper comparison of “control and treatment groups.” A crossover design of the study with both course guides been used in parallel by two groups of the same admission year was not possible for organizational and financial reasons. In addition, a crossover study bears the inherent risk that interactions between CACI and WB students bias the results due to group interferences. We think that our study allows us to conclude that e-learning as used in our laboratory course is a necessary adaptation to current techniques of information retrieval that decision makers should take into consideration. Unfortunately, we could not objectively compare learning success, but the absence of a significant difference between both teaching methods regarding subjective gain in knowledge is in agreement with several studies that found no difference in learning success.

Naturally, the use of e-learning as an electronic substitute for paper instruction in our course module doesn’t exploit today’s computer capabilities. The uses of e-learning in new teaching/learning situations (e.g., virtual patients or virtual medical environments) offers entirely new avenues for teaching, and further research is needed before our conclusions can be extrapolated to these approaches.

DISCLOSURES

No conflicts of interest, financial or otherwise, are declared by the author(s).

AUTHOR CONTRIBUTIONS

Author contributions: E.F., M.F., and S.G. approved final version of manuscript; E.F., and M.F. interpreted results of experiments; E.F. prepared figures; E.F., M.F., and S.G. performed experiments; E.F., M.F., and S.G. analyzed data; E.F. and M.F. interpreted results of experiments; E.F. prepared figures; E.F. and S.G. drafted manuscript; E.F., M.F., and S.G. edited and revised manuscript; E.F., M.F., and S.G. approved final version of manuscript.

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