Use of Technology in Dental Education

A Model of Blended Learning in a Preclinical Course in Prosthetic Dentistry

Daniel R. Reissmann, DDS, Dr med dent; Ira Sierwald, DDS, Dr med dent; Florian Berger, Dipl-Ing (FH); Guido Heydecke, DDS, Dr med dent habil

Abstract: The aim of this study was to evaluate the use of blending learning that added online tools to traditional learning methods in a preclinical course in prosthetic dentistry at one dental school in Germany. The e-learning modules were comprised of three main components: fundamental principles, additional information, and learning objective tests. Video recordings of practical demonstrations were prepared and cut into sequences meant to achieve single learning goals. The films were accompanied by background information and, after digital processing, were made available online. Additionally, learning objective tests and learning contents were integrated. Evaluations of 71 of 89 students (response rate: 80%) in the course with the integrated e-learning content were available for the study. Compared with evaluation results of the previous years, a substantial and statistically significant increase in satisfaction with learning content (from 30% and 34% to 86%, p<0.001) and learning effect (from 65% and 63% to 83%, p<0.05) was observed. Qualitative evaluation revealed mostly positive responses, with not a single negative comment regarding the blended learning concept. The results showed that the e-learning tool was appreciated by the students and suggest that learning objective tests can be successfully implemented in blended learning.

Keywords: dental education, blended learning, e-learning, online course, prosthodontics, preclinical education, Germany

Submitted for publication 12/6/13; accepted 7/19/14

During their dental education, students have not only to gain and prove theoretical knowledge and values but also to acquire practical skills. These skills require students to learn the theoretical background (e.g., rules of tooth preparation or indications for partial prostheses) and how to carry out procedures (e.g., to prepare teeth and manufacture fixed and removable dentures). Students acquire their practical skills by performing several practical exercises, which are demonstrated beforehand, and the theoretical background is presented in lectures and seminars. When the theoretical lectures are distant in time from practical implementation, students must see demonstrations of the practical procedures with only a little theoretical background.

A solution to overcome the shortcomings of traditional didactic methods is to incorporate computer-aided learning (e-learning), which allows students to work in their own manner and at their own time and pace. Furthermore, e-learning can decrease classroom time and increase students’ engagement with learning content. The combination of traditional teaching methods with modern information technologies—known as blended learning—takes advantage of the benefits of both types of instruction. Blending learning combines the best of both worlds: information is available for students independent of time and space, and experiences can be exchanged with real persons. Students have been found to prefer blended learning over traditional face-to-face learning or e-learning alone. Although blended learning requires technical infrastructure, planning, and implementation, it can result in greater faculty effectiveness and overall efficiency.

Blended learning has already been employed in dental education and has shown significant applicability. Dental students have reported a positive attitude towards the integration of e-learning in general and the web-based learning of dental morphology in particular. Furthermore, blended learning
Germany. All students of the class participated in the course with the integrated digital learning content. For comparisons, data from two courses in previous years without the blended learning model (2009: 60 students; 2010: 56 students) and three courses in subsequent years with the blended learning model (2011: 51 students; 2012: 48 students; 2013: 69 students) were also included in the analyses. This evaluation of the project was considered exempt by our institution’s Institutional Review Board since data were collected for standard quality assurance and information was recorded in a manner in which students cannot be identified.

The formerly used teaching methods (lectures, seminars, and course outlines) were supplemented by e-learning modules, which replaced practical demonstrations of dental and technical procedures. E-learning modules were prepared for two practical procedure demonstrations: 1) post and core module: tooth preparation and placement of a post and a core, covered with a provisional crown; and 2) fixed dental prosthesis (FDP) module: tooth preparation and manufacturing and insertion of an FDP. The total course time for the post and core module was 32 hours, including two one-hour practical demonstrations. The total course time for the FDP module was 37 hours, including three one-hour practical demonstrations. However, the practical demonstrations were only part of the course without blended learning and were then replaced by the e-learning modules in the course that began to integrate blended learning. The student-faculty ratio for all courses was approximately 30:1.

The e-learning modules covered three main components: fundamental principles, additional information, and learning tests. First, the content that should be integrated was structured, and information considered essential to successfully perform the practical work during the course and to pass the course, as well as additional information helpful to the students, was defined. Second, short learning objective tests were developed and coordinated with the appropriate course content. These components were meant to be combined into blocks of single learning goals (Figure 1). Finally, the learning objective tests were used in order to restrict student access to the subsequent contents and to boost motivation to move on to the next lesson.

For the fundamental principles components, professional videos of short sequences of single learning goals were prepared (Figure 2) and supplemented by additional oral instructions recorded...
The e-learning module was implemented using the existing technical infrastructure (OLAT e-learning platform) of the University of Hamburg. Text-based information was formatted using HTML, which can be readily deployed in OLAT. The fundamental video demonstrations were encoded in FLV format, and an Adobe Flash-based open source video player was used for playback. As a result, the complete online course material could be accessed through those browsers capable of supporting flash video files. Students could access the new e-learning application before lectures, at home, or elsewhere, even during course time in the classroom. Therefore, two computer workstations with web access were set up in the course room as well.

As part of the standard quality assessment of dental education at the university, the students evaluated the course after completion by means of ten questions of varied focus (e.g., motivation and support of instructors, exercise options, organization). Responses were made on a six-point ordinal rating separately from the films. Videos ranged in length from seconds to minutes and contained the complete practical demonstrations of dental and technical procedures (e.g., tooth preparation, impression, model fabrication, wax-up, molding). The e-learning sites with the video recordings also contained corollary text and visual images, such as written instructions, photographs, and/or close-up images of the procedures demonstrated. For the additional information components, supplementary e-learning contents were employed using web-based text information and images. These links offered extended information on the current topic (e.g., ergonomics, precaution, armamentarium, preparation techniques, impression materials, sources of error).

Finally, learning objective tests with feedback about the students’ learning progress, aimed at increasing motivation, were integrated. The test questions were adapted from a collection of questions from the final exam. All were multiple-choice questions. An incorrect answer prompted feedback about why the answer was incorrect. The student could therefore repeat the tests as often as necessary to pass, with successful completion resulting in unlocking the next video sequences and learning units.

Figure 2. Still images of four movie sequences used in e-learning modules
scale, with 6=highest level of agreement. Two questions were most indicative of students’ satisfaction with e-learning modules: “The provided teaching material was helpful for preparation for and post-processing of the course” and “I learned important things in the course.” These two questions were used to assess the effect of the e-learning application.

The results were evaluated by calculation of mean and standard deviation (SD) of the students’ ratings. Additionally, scores were dichotomized using the values 4-6 (positive half of the scale) to indicate agreement and the values 1-3 (negative half of the scale) for non-agreement. The results were compared to those from the two previous courses (held one and two years prior), which were also evaluated as part of the regular course assessment. The previous courses did not differ in content from the more recent offerings, but only by addition of the e-learning application. Furthermore, students’ evaluations of the three subsequent courses after implementation of the e-learning module were utilized for long-term assessment. Thus, differences in evaluations between courses with and without e-learning can be interpreted as the effect of the new application.

To compute the overall magnitude of change in satisfaction due to blended learning, linear regression analyses were computed with e-learning as the predictor and the two items regarding students’ satisfaction with e-learning modules as criterion variables. Furthermore, calculation of effect size (Cohen’s d) was used to determine the strength of change. An effect size of d=0.2 was considered to be small, 0.5 medium, and 0.8 large. Proportions of agreement were tested using chi-squared test. All analyses were performed using the statistical software package STATA, Release 13 (StataCorp., College Station, TX, USA) with the probability of a type I error set at 0.05.

In addition to the questions with the six-point ordinal response format, students were asked to provide free-text comments in three areas: praise, criticism, and suggestions. Comments related to the e-learning modules were available only from students in the premier course with integrated digital learning content. Comments were evaluated based on guidelines for qualitative content analyses. First, single statements in these comments were identified since some comments contained more than one statement. Second, statements were allocated to praise, criticism, and suggestions. Third, statements regarding the same topics were grouped. Only topics mentioned more than once were considered as relevant in the analysis. Finally, allocations and groupings were checked to ensure correct identification of topics and to avoid misclassification. Results of content structuring and definition of topics were presented as a summarizing content analysis.

Results

Evaluations of 71 of the 89 students (response rate: 80%) in the course with the integrated e-learning content were available for inclusion in the study. Each of the two newly developed e-learning modules (post and core module, FDP module) began with a preliminary test to assess basic knowledge. The post and core module contained seven additional learning objective tests, resulting in a total of eight blocks comprising the three main components: fundamental principles, additional information, and learning objective tests (Figure 1). The FDP module contained ten tests, for a total of ten blocks.

While no substantial difference in ratings of the usefulness of learning material was observed between the two courses without the e-learning modules (t-test: p=0.271), ratings for the courses with the e-learning modules were better than the ratings for the comparison groups with a large effect size (p<0.001; Table 1). These positive ratings resulted in a substantially and statistically significant higher proportion of agreement and, therefore, more satisfaction among the students enrolled in the e-learning modules (71% to 96%) than among the students one and two years prior (30% and 34%; chi-squared test: p<0.001; Figure 3).

Results for the ratings of learning effects were comparable to the ratings of learning materials, but differences were smaller and effect size was only moderate. Evaluation of reported learning effects was significantly better in students with e-learning than in students without (p<0.001; Table 1), with no statistically significant differences between both comparison groups one and two years prior to e-learning (t-test: p=0.678). Accordingly, students in the e-learning courses were more satisfied with the learning effect (79% to 87%) than students one year (65%) or two years prior (69%; chi-squared test: p=0.001; Figure 4).

A total of 62 students provided comments on the e-learning course, with 69 isolated statements. The qualitative evaluation revealed very positive responses, with comments such as “good alternative to local demonstrations” and “complementary knowledge . . . very useful, also for preparation of
implementation of the e-learning modules (N=17); most of the critical responses were related to lack of consistency between course and e-learning content (N=6); and suggestions were made most often with respect to further optimization of the e-learning content (N=3).

When the specific content of the comments was classified and only statements identified more than once were considered, a total of 47 statements in the e-learning course provided praise, 12 provided criticism, and seven made suggestions (Figure 5). Most of the positive responses were related to exams.” When the specific content of the comments was classified and only statements identified more than once were considered, a total of 47 statements in the e-learning course provided praise, 12 provided criticism, and seven made suggestions (Figure 5). Most of the positive responses were related to

Table 1. Students’ ratings in two groups without e-learning (2008 and 2009) and in courses with e-learning modules (2010 to 2013)

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
<th>2010†</th>
<th>2011†</th>
<th>2012†</th>
<th>2013†</th>
<th>Coefficient (95% CI)</th>
<th>p-value</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning material</td>
<td>2.6</td>
<td>2.9</td>
<td>4.8</td>
<td>4.8</td>
<td>4.2</td>
<td>5.1</td>
<td>2.0 (1.7; 2.3)</td>
<td>&lt;0.001</td>
<td>1.53</td>
</tr>
<tr>
<td>Learning effect</td>
<td>4.0</td>
<td>3.9</td>
<td>4.6</td>
<td>4.5</td>
<td>4.6</td>
<td>4.8</td>
<td>0.6 (0.4; 0.9)</td>
<td>&lt;0.001</td>
<td>0.53</td>
</tr>
</tbody>
</table>

*Courses with e-learning modules
SD=standard deviation; CI=confidence interval

Note: Coefficients and p-values based on linear regression analysis. Effect size based on Cohen’s d. Number of students and male-female percentages for each year were as follows: 2008 N=60, 26% male, 74% female; 2009 N=56, 25% male, 75% female; 2010 N=71, 29% male, 71% female; 2011 N=51, 41% male, 59% female; 2012 N=48, 35% male, 65% female; and 2013 N=69, 34% male, 66% female.

Figure 3. Agreement (satisfaction) of students with helpfulness of learning material by year of course attendance

Note: Values above bars show agreement in percentage.
learning effects and satisfaction with the learning material, which should correspond to the students’ performance, although such an inference should be made with caution. Since the e-learning application provided not only standardized and web-based access to the learning content but added more time to the students in the course due to reductions of live demonstrations, a certain proportion of the increase in students’ satisfaction could be related to the increase in available time and not specific to the e-learning content. This may be considered a limitation of the study. However, time potentially gained due to reductions of live demonstrations was less than 10% of the overall course time. It is therefore more likely that the increase in students’ satisfaction is related to the specific e-learning content. Even though students’ ratings varied between different years, satisfaction was consistently higher in courses with the e-learning content than in courses without it.

The observed positive effect of blended learning on students’ satisfaction agrees with results from previous studies.11-14,20 No study in dentistry was

Discussion

By providing the students with the interactive e-learning contents, a digital “tutor” was incorporated into the course with established learning concepts. The results showed that this web-based learning significantly improved the satisfaction of the students.

The study findings suggest that instructor-based practical demonstrations in preclinical courses in prosthetic dentistry can be successfully replaced by e-learning applications when course content is structured according to specific predefined learning goals and procedures. Furthermore, no negative effects of learning objective tests and corresponding access restrictions to the subsequent contents were observed in the students’ comments. However, only the students’ perspective was evaluated, and no objective measures of performance such as standardized knowledge tests or time required were assessed. Nonetheless, the students’ evaluations could be considered as a global rating of perceived learning effects and satisfaction with the learning material, which should correspond to the students’ performance, although such an inference should be made with caution. Since the e-learning application provided not only standardized and web-based access to the learning content but added more time to the students in the course due to reductions of live demonstrations, a certain proportion of the increase in students’ satisfaction could be related to the increase in available time and not specific to the e-learning content. This may be considered a limitation of the study. However, time potentially gained due to reductions of live demonstrations was less than 10% of the overall course time. It is therefore more likely that the increase in students’ satisfaction is related to the specific e-learning application. Even though students’ ratings varied between different years, satisfaction was consistently higher in courses with the e-learning content than in courses without it.

The observed positive effect of blended learning on students’ satisfaction agrees with results from previous studies.11-14,20 No study in dentistry was

Figure 4. Agreement (satisfaction) of students with learning effect by year of course attendance

Note: Values above bars show agreement in percentage.
identified reporting negative effects on students’ satisfaction. However, results regarding objective measures of students’ performance are contradictory. While previous studies have reported better student grades after integration of blended learning in a pre-clinical course in complete denture prosthodontics, and better results in an oral radiology post-course knowledge test, others found no effect on students’ performance or academic results. Due to the conflicting results of previous reports and the lack of objective measures in our study, it remains unclear whether blended learning can increase students’ performance in preclinical courses in dentistry simultaneously with the effect on students’ satisfaction. This relationship warrants further research.

The newly developed blended learning model has strengths and limitations. Major strengths of the applied model are the uniform and standardized delivery of information, flexibility for students due to permanent availability of the e-learning contents, and integration of learning objective tests for additional learning motivation and interactivity. However, these aspects also imply some limitations. Before blended learning can be integrated into the dental study, the e-learning content has to be developed. This requires substantial effort, costing both time and money.

Furthermore, web-based e-learning requires that the students have access to the Internet. Even though 89% of English undergraduate dental students were found to have web access at home in 2004, this does not necessarily mean that all current students in all countries have this option. For our students without access at home, the online course was available at the university, either in the classroom during course time or at public computers in the library at any time. All students also had the opportunity to review the e-learning modules during course time. Another blended learning approach is the provision of additional interactive tutorials and exercises on a CD-ROM or DVD. Although this seems to be promising for students without web access, there are substantial disadvantages to such a solution. Students still need a player for the disk, but most importantly, the information on the disks cannot be updated and there is limited possibility to combine it directly with learning checks. Moreover, it cannot be assessed
whether students actually viewed the content and performed the included tasks.

As has been shown by faculty evaluations of e-learning, major barriers to educators using this new style of learning are the supposed negative effect on in-person lecture attendance and the ability for students to plagiarize. However, in our study, e-learning was not intended to provide lecture content solely on an electronic basis but to replace the demonstrations during course time in order for students to repeat and achieve learning goals to their satisfaction. Therefore, a negative effect on lecture attendance was not expected. Furthermore, plagiarism was not an issue as the e-learning modules were not used for exams. Of course, students may have worked together to pass the learning objective tests in the e-learning modules; this was not prohibited since the tests were intended as stimulation for the students to think and learn about their work rather than to serve as a formal exam.

A methodological limitation of this study is that the students were not randomized into groups with and without blended learning contents as was done in another study. However, this was not possible for us as the course was a fixed part of the curriculum and could not differ among subgroups of students in one course. Furthermore, the course took place in one room for all students at the same time. This did not allow for different methods of demonstrations (local vs. web-based). Instead, the results of the students’ course evaluations were compared with those of the two previous years’ courses, which did not utilize blended learning. Since the courses differed not only in whether or not blended learning was used but also in the year and context in which they took place, other factors could have potentially affected the satisfaction scores. Therefore, differences in scores in courses with blended learning and in courses without would represent the combination of normal fluctuations in students’ ratings and effects of external factors. This would explain the variability of the satisfaction scores observed in our study. No substantial changes in presenting the learning material were performed besides the implementation of blended learning, so scores from different years were assessed and combined to minimize the impact of external, contextual factors. Therefore, differences in students’ satisfaction should mainly represent true effects of blended learning.

Due to university regulations, no additional information could be collected that was not already covered in the standard quality assessment of dental education. Only the results of the quality assessment relevant to the e-learning content were evaluated, supplemented by written comments. Although specific effects of the new course could not be assessed, the available information provided a coherent impression about the mainly positive impact of blended learning on students’ satisfaction and allowed for identifying further topics for improvement.

Conclusion

The blended learning methodology assessed in this study represents a promising add-on to existing educational methods and was appreciated by the students. The results suggest that learning objective tests and corresponding access restrictions can be successfully implemented in blended learning. Even though blending learning had a positive impact on these students’ satisfaction with learning material and learning effect, future studies should also include objective measures of students’ performance.

Acknowledgments

This project was in part funded by a grant from the University of Hamburg to support the development of e-learning contents. We are grateful to Dr. Daniela Bender, Dr. Marie-Therese Paul, Dr. Nele Kettler, Dr. Anika Reul, Dr. Nina Menden, Dr. Mareike Bürhrens, Dr. Daniel Farhan, Dr. Ingo Kirsch, Dr. Sascha Pieger, and Mr. Gerhard Preller (University Medical Center Hamburg-Eppendorf) for their help with preparing the e-learning contents; Ms. Barbara Gabain and Mr. Helge Brumme (University of Fine Arts Hamburg) for performing the video and audio recordings and the film post-production; and Ms. Andrea Medina (University of Minnesota) for her valuable comments on an earlier version of the manuscript.

REFERENCES