Improved Student Performance Following Instructional Changes in a Problem-Based Learning Curriculum

Teresa A. Marshall, Ph.D.; Michael W. Finkelstein, D.D.S., M.S.; Fang Qian, Ph.D.

Abstract: Problem-based learning (PBL) supplements the traditional curriculum at the University of Iowa College of Dentistry and is used to introduce basic critical thinking skills and evidence-based dentistry. The objective of this article is to describe instructional changes made in response to student and faculty concerns and to compare the quality of student performance before and after the instructional changes. Instructional changes introduced in fall 2008 included replacing one learning report with a structured peer-reviewed manuscript critique in each of four cases, having the same course director evaluate all written assignments rather than facilitating faculty members, and eliminating midterm and final assessment cases. The final learning reports from first-year dental students entering dental school in fall 2007 were compared to the final reports of students entering in fall 2008. Final learning reports were evaluated using course grading criteria. Scores for students from fall 2008 were higher than those from fall 2007 for overall performance ($p<0.001$), overall background quality ($p<0.001$), overall clinical significance ($p<0.001$), and overall reference quality ($p<0.001$) as well as for individual components within each category. These results suggest that the implemented instructional changes were effective in improving student performance and reinforce the need to evaluate and revise instructional strategies in response to student and faculty concerns.

Dr. Marshall is Associate Professor, Department of Preventive and Community Dentistry, College of Dentistry, University of Iowa; Dr. Finkelstein is Professor, College of Dentistry, University of Iowa; and Dr. Qian is Associate Research Scientist, Department of Preventive and Community Dentistry, College of Dentistry, University of Iowa. Direct correspondence and requests for reprints to Dr. Teresa A. Marshall, Department of Preventive and Community Dentistry, College of Dentistry, University of Iowa, 335 N DSB, Iowa City, IA 52340; 319-335-7190 phone; 319-335-7187 fax; teresa-marshall@uiowa.edu.

Keywords: problem-based learning, instructional changes, educational outcome evaluation, dental education

Submitted for publication 4/21/10; accepted 7/27/10

Dental educators increasingly recognize the need for students to develop lifelong learning skills in preparation for a career in dentistry.[1-4] The quantity and relative quality of scientific information continue to explode, while the Internet has increased accessibility to both scientific and nonscientific information—providing a platform for anyone's two cents. For today's student to successfully process the wealth of information available and articulate rational arguments for or against health-related claims, educational curricula have focused on providing instruction in critical thinking and evidence-based dentistry. Problem-based learning (PBL) is an educational strategy used to teach independent learning with emphasis on critical thinking and evidence-based dentistry.

In PBL, new knowledge is integrated with recalled knowledge in the context of a multidisciplinary patient problem using a self-directed, student-driven group process.[3] PBL curricula can be designed as either the primary or a supplementary educational strategy within an institution. The objectives and outcomes of the PBL process are also defined by the institution's educational mission. At the University of Iowa, PBL supplements the traditional curricula with the primary goal of teaching fundamentals of critical thinking and evidence-based dentistry.[5] At the most basic level, student outcomes include developing questions (i.e., identifying what information is desired), identifying resources to address the question, learning to read the scientific literature, and demonstrating independent learning skills.

With any educational strategy and particularly with PBL, in which there are typically no right or wrong answers, the mechanism by which the educator "teaches" will have a direct impact on student learning.[6] Successful educators 1) identify the desired student behaviors and outcomes, 2) clearly communicate expectations to students, and 3) provide constructive feedback to students regarding performance and the

gap between expectations and performance.[6] Neither educational strategies nor curricular content are stagnant; both evolve and grow in response to student performance, instructor growth, and either internal or external critique of the curriculum.

In response to internal criticism of Iowa's PBL curriculum, the course directors implemented several instructional changes between the fall 2007 and fall 2008 classes. The objectives of this article are to define the instructional changes and to compare the quality of student performance on written learning reports completed by students before and after implementation of the changes.

Methods

Problem-based learning has been used to introduce first-year dental students to the concepts of critical thinking, reading the scientific literature, and evidence-based dentistry at the University of Iowa for more than ten years. Following an introductory developmental phase, the curriculum evolved to include a series of content lectures, four facilitated cases, and two assessment cases. Facilitated cases were each three sessions in length, evenly distributed throughout the school year. Assessment cases were each two sessions in length, completed independent of facilitators and scheduled as midterm and final exercises.

A traditional PBL format in which students were expected to identify facts, clinical gaps, and problems and develop hypotheses and learning issues was followed for all cases.[3,5] Students were expected to research learning issues, prepare written learning reports, and share their new knowledge with their peers at sessions 2 and 3 for facilitated cases and at session 2 for assessment cases. Group facilitators evaluated learning reports from facilitated cases, while course directors evaluated learning reports from assessment cases. Facilitators were trained regarding the evaluation protocol, and consistent criteria were used for both facilitated case and assessment case evaluations.

Although the PBL curriculum functioned and course objectives were achieved, several recurring concerns were identified. Students complained of uneven feedback amongst facilitators on facilitated case learning reports; complaints were supported by uneven performance on assessment case learning reports evaluated by course directors. Limited facilitator critique and/or feedback enabled some students to avoid using peer-reviewed research articles as the source of information for learning reports or to read only abstracts, resulting in a limited understanding of the basics of research design and scientific evidence. Students who received minimal feedback, and thus limited incentive to further develop their skills, perceived learning reports to be "busy work." Although facilitators by and large enjoyed the PBL process, they likened evaluating learning reports to punishment, and facilitator burnout became a significant concern. The course directors recognized the legitimacy of student and facilitator concerns and their impact on student outcomes. Avoidance of reading and critiquing peer-reviewed research articles limited student growth in critical thinking and the foundation for future evidence-based practice.

In response to these concerns, the course directors evaluated the PBL curriculum with the objective of maintaining the interactive PBL process while improving student performance. Specifically, our goal was for all students to read peer-reviewed research articles and use peer-reviewed science to develop background information within their learning reports. Three fundamental changes affecting written assignments (decreased number of learning reports, addition of resource assignment, and elimination of assessment case) were implemented in fall 2008; there were no changes in the lecture content, PBL case process, case development, or written evaluation criteria.

First, facilitated case written assignments were changed from two learning reports (due in sessions 2 and 3) to one resource assignment (due in session 2) and one learning report (due in session 3). The resource assignments (defined in Figure 1) were structured to critique a lay resource (case 1), one peer-reviewed research article (case 2), two peer-reviewed research articles having different research designs (case 3), and two peer-reviewed research articles having different outcomes (case 4). The guidelines provided to structure the resource assignments were based on content provided to both current and previous classes and served as criteria for evaluation. Guidelines for structuring and criteria for evaluating learning reports (defined in Figure 1) did not change; the same form was used to provide written feedback.

Second, the primary course director (TAM) assumed responsibility for grading all written resource assignments and learning reports to limit concerns of uneven facilitator feedback, while the secondary course director (MWF) screened a random sample of assignments as well as assignments with outlying scores to confirm fairness of evaluation. Finally, the

Resource assignments are assigned criteria designed to aid the student's evaluation of a resource selected to address his or her learning issue (i.e., question of interest). The resource assignments differ for each case as assignments evolve with student growth.

Example: Case 2

Objective: Review search strategies and article critique.
Given your selected learning issue:

1. Outline your search strategy of the scientific literature:
    a. Record the search engines or other tools used to identify resources.
    b. Record the key words and "success" of key words used in searching the literature.
    c. Identify the difficulties encountered in finding articles.
    d. Following your search, identify how you would change your strategy next time.
2. Select one research article that appears relevant to your learning issue.
3. Critique the chosen article using criteria discussed in class:
    a. Research question (or hypothesis).
    b. Study design.
    c. Study population.
    d. Gross methodology.
    e. Key results.
    f. Secondary results.
    g. Limitations.
    h. Author's primary conclusion.
    i. Do the results support the author's conclusion?
    j. Summarize the article.
    k. How does the article link to your learning issue?

Learning reports are the student's written response to his or her learning issue. The learning report is comprised of four sections: the learning issue, background information, clinical relevance to the patient, and references.

Figure 1. Definitions of resource assignments and learning reports in the PBL curriculum

assessment cases were eliminated as students were already receiving consistent feedback on facilitated case learning reports.

The study design is cross-sectional: the performance of students entering dental school in fall 2007 (n=80) was compared to the performance of dental students entering in fall 2008 (n=80). Students (n=4) who took a leave of absence from dental school and/or did not complete the course were excluded from analyses leaving n=79 and n=77 students, respectively, for fall 2007 and fall 2008 classes. This study was classified as exempt from federal regulations by the University of Iowa's Institutional Review Board.

Students are assigned to two sets of groups at the beginning of the year. A departmental assistant randomly assigns the students to the first set of groups; no background information (i.e., Dental Admission Test scores or grade point average) is used to balance groups. The second set of groups is randomly assigned, but arranged such that no two students from the same group in the first set are together in the second set. The first set of groups are together for cases 1 and 2 (first semester), while the second set of groups are together for cases 3 and 4 (second semester). Students do not have any say regarding group assignment.

For this study, the final learning reports were individually scored by the primary course director using the criteria in Table 1. The criteria reflect guidelines provided to students for structuring learning reports and the evaluation criteria used for grading purposes, albeit structured in a more comprehensive fashion.

The learning report grade was obtained from student records. Scores for final learning reports completed by the fall 2007 class (final assessment case) were compared to the final learning reports (case 4) completed by the fall 2008 class. Twenty-eight percent of scored reports were selected for critique by the secondary course director. The selected reports represented twenty-two reports from the fall 2007 class and twenty-two reports from the fall 2008 class; half of each class's reports were selected from initial and final evaluations to minimize bias associated with order of evaluation. Course directors agreed unanimously on score assignment.

Descriptive statistics were calculated for student scores. The chi-square test, Fisher's exact test, and nonparametric Wilcoxon rank-sum test were conducted to compare scores between the fall 2007 and fall 2008 classes.

Results

Demographic information for first-year dental students entering in fall 2007 and fall 2008 are presented in Table 2. Gender, age, state residency, grade point average, and Dental Admission Test score distributions were very similar; however, fewer students entered dental school with a minimum bachelor's degree in fall 2007.

Scores for learning report components for the fall 2007 and fall 2008 classes are presented in Table 3. Students from both classes defined their learning issues, and most learning issues were broad or not focused for both classes. Most students from both classes included an introduction to their learning issue within their background information. Fewer students from the fall 2007 class included research article summaries; however, of students who summarized articles, similar numbers of students from each class included key components. The overall quality of article summaries was higher for the fall 2008 class than for the fall 2007 class; more students from the fall 2008 class provided evidence of reading articles beyond the abstract content. Students from the fall 2008 class who summarized articles also summarized more articles than the fall 2007 class did. The fall 2008 class had higher overall background scores than the fall 2007 class.

Although similar numbers of students from the two classes linked their learning issue to the patient's concern, fewer students from the fall 2008 class addressed future treatment plans for the patient

Table 1. Criteria for scoring learning reports

Evaluation Component	Score
Learning Issue	
Is the learning issue defined?	yes/no
Is the learning issue broad and unfocused?	yes/no
Background	
Is the rationale for the learning issue presented?	yes/no
Is a research article summarized? If so:	yes/no
Is the research question/objective defined?	yes/no
Is the study design identified?	yes/no
Is the population specified?	yes/no
Is the gross methodology identified?	yes/no
Are key results provided?	yes/no
Are secondary results provided?	yes/no
Is the significance of the results presented?	yes/no
Are limitations identified?	yes/no
What is the relative summary quality?	1 to 5
Is there evidence of reading beyond the abstract?	yes/no
How many research articles are summarized?	0 or more
Is the background summarized?	yes/no
Is the learning issue addressed?	yes/no
What is the relative background quality?	1 to 5
Clinical Significance	
Is the learning issue linked to the patient problem?	yes/no
Is the chief complaint/treatment plan addressed?	yes/no
What is the relative clinical significance quality?	1 to 5
References	
Are the references appropriate for the learning issue?	yes/no
Are peer-reviewed research articles cited?	yes/no
How many peer-reviewed research articles are cited?	0 or more
What is the relative reference quality?	1 to 5
What was the course-assigned learning report grade?	1 to 15

Table 2. Class profile at admission

Variable	Fall 2007 Class	Fall 2008 Class
Gender (Male)	58%	61%
State of residence (Iowa)	71%	71%
Age, in years (mean [range])	24 [21–41]	23 [21–39]
Cumulative grade point average (mean)	3.69	3.69
Dental Admission Test score (mean)	19	19
Bachelor's degree	76%	98%

Note: Bachelor's, master's, and doctoral degrees were held at the time of admission.

Table 3. Comparison of learning report component scores of students entering dental school in fall 2007 to those entering in fall 2008

Evaluation Component	Fall 2007 n=79	Fall 2008 n=77	p-value
Learning Issue			
Defined learning issue	100%	99%	0.494[a]
Broad learning issue	87%	77%	0.081[b]
Background			
Introduced learning issue	94%	100%	0.059[a]
Summarized article	63%	82%	0.010[b]
Research question/objective	78%	76%	0.820[b]
Study design	48%	48%	0.978[b]
Population	92%	84%	0.258[a]
Methodology	82%	76%	0.453[b]
Key results	100%	98%	0.999[a]
Secondary results	50%	60%	0.273[b]
Significance of results	66%	86%	0.013[b]
Limitations	34%	25%	0.318[b]
Summary quality[c]	3.5±1.1	4.4±0.7	<0.001[d]
Evidence of reading beyond abstract	70%	90%	0.005[b]
Number of articles summarized[c]	1.1±0.7	1.8±0.5	<0.001[d]
Summarized background	35%	38%	0.774[b]
Addressed learning issue	99%	100%	0.999[a]
Background quality[c]	3.2±1.0	4.3±1.0	<0.001[d]
Clinical Significance			
Linked learning issue to patient	94%	100%	0.059[a]
Treatment plan	87%	66%	0.002[b]
Clinical significance quality[c]	3.2±0.6	3.8±0.7	<0.001[d]
References			
Appropriate for learning issue	96%	100%	0.245[a]
Cited research articles	81%	100%	<0.001[a]
Number of research articles cited[c]	1.5±0.6	2.0±0.6	<0.001[d]
Reference quality[c]	3.0±0.7	4.4±0.8	<0.001[d]
Learning report grade[c]	9.4±1.9	12.5±2.2	<0.001[d]

Notes: Percentages indicate percentage of yes scores.
[a]Fisher's exact test; [b]chi-square test; [c]mean of numerical scores; [d]Wilcoxon rank-sum test

(Table 3). Regardless, the quality of the overall clinical significance was scored higher for the fall 2008 class than for the fall 2007 class. Students from both classes selected articles appropriate for their learning issues. However, more students from the fall 2008 class than the fall 2007 class cited the primary literature, and they cited more research articles. The overall quality of references was scored higher for the fall 2008 class than the fall 2007 class.

Grades assigned to learning reports during the respective terms were also compared (Table 3). The grades for the fall 2008 class were 30 percent higher than grades for the fall 2007 class, which is consistent with the fall 2008 class having higher overall background, clinical significance, and reference scores.

Discussion

The results reported here support our hypothesis that targeted instructional changes improved student performance. Course grades as well as overall background, clinical significance, and resource scores were higher following repeated critique of research articles, consistent facilitator feedback, and elimination of the assessment cases. Because the instructional changes occurred simultaneously, one cannot identify which change contributed to the improved scores.

The improvement in student performance also reinforces the importance of regularly critiquing one's curriculum, attempting to understand criticisms, and developing strategies to address the central issues.

Although it is easy to disregard students' complaints about "busy work," recognizing that this perception has a basis (i.e., student effort vs. perceived benefit; vague vs. concrete feedback), evaluating the instruction's role in students' perception, and identifying strategies to address the students' perception are important. Furthermore, when student performance is adequate but not outstanding, critique of the instruction including the content, assignments, expectations of students, and communication of expectations to students can identify weaknesses.[7] Development of strategies to respond to such weaknesses leads to course evolution. In this article, we've outlined the criticism of our curriculum and our response to such criticism. In addition, we were able to analyze before and after data and document the impact of instructional changes on student performance. Although student performance is improved, it would be premature to suggest that the course is "done." Continued critique by both students and faculty members will likely identify additional areas for improvement.

Student performance by both classes provides documentation that students are achieving PBL curricular objectives at a novice level. The learning reports are designed to evaluate the student's ability to form questions, identify resources, and read the literature independently. The data suggest that students are defining their questions, but not yet focusing their questions. The data also suggest that students identify appropriate primary research articles to address their learning issue. Most but not all students are summarizing their research articles, albeit at a novice level. The article summary provides evidence that the student has internalized the content and is able to communicate this information. This study assessed whether or not students included key components within their summaries, but did not evaluate the depth and completeness of the component assessment. This course is the first time most students were expected to read the primary literature, and they do not have the experience to critique it at a proficient level.

This study has several limitations, most notably those associated with the study design. The intervention occurred between classes rather than having half of each class receive different instruction. Other curricular changes and/or inherent differences between classes could account for the observed differences in student performance. Class profiles of students entering in fall 2007 and fall 2008 were virtually identical with the exception of undergraduate degrees since fewer students in the fall 2007 class had a bachelor's degree at the time of admission. It is possible that the additional coursework required for degree completion led to a more knowledgeable or mature student that accounted for the results obtained in our study. A third limitation concerns the impact of improved scores. The results reported here suggest that students from the fall 2008 class are more capable of reading and critiquing the scientific literature in response to a patient problem; however, the study cannot determine whether the class is better prepared to translate such skills to clinical practice.

In conclusion, our study supports the role of regular critique and modification of instructional strategies with respect to desired outcomes. Evaluation of outcomes in response to changes in instructional strategies is necessary to judge the appropriateness and/or success of the instructional change. Although we have reported evidence of improved student performance, improved student perceptions and decreased faculty burden are also valuable outcomes.

REFERENCES

1. Hendricson WD, Andrieu SC, Chadwick DG, Chmar JE, Cole JR, George MC, et al. Educational strategies associated with development of problem-solving, critical thinking, and self-directed learning. J Dent Educ 2006; 70(9):925–36.
2. Campbell SD. Learning from the present to educate the future: dental education and EBDM. J Evid Base Dent Pract 2009;9:154–7.
3. Finchan AG, Shuler CR. The changing face of dental education: the impact of PBL. J Dent Educ 2001;65(5): 406–21.
4. Johnsen DC, Finkelstein MW, Marshall TA, Chalkley YM. A model for critical thinking measurement of dental student performance. J Dent Educ 2009;73(2):177–83.
5. Marshall T, Finkelstein M, Cunningham-Ford M. Problem-based learning: a vehicle to teach critical thinking, reading the scientific literature. MedEdPORTAL, 2010. At: http://services.aamc.org/30/mededportal/servlet/s/segment/mededportal/find_resources/browse/?subid=7931. Accessed: March 14, 2011.
6. Diamond RR. Chapter 11: designing the learning experience. In: Diamond RM, ed. Designing and assessing courses and curricula. San Francisco: Jossey-Bass, 1998:153–67.
7. Sudweeks RR, Diamond RM. Resource A: questions for evaluating a college course. In: Diamond RM, ed. Designing and assessing courses and curricula. San Francisco: Jossey-Bass, 1998:241–6.