Effect of Digital Problem-Based Learning Cases on Student Learning Outcomes in Ophthalmology Courses

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Objective: To assess the impact of digital problem-based learning (PBL) cases on student learning in ophthalmology courses.

Methods: Ninety students were randomly divided into 3 classes (30 students per class). The first class studied under a didactic model. The other 2 classes were divided into 6 groups (10 students per group) and received PBL teaching; 3 groups studied via cases presented in digital form and the others studied via paper-form cases. The results of theoretical and case analysis examinations were analyzed using the $\chi^2$ test. Student performance on the interval practice was analyzed using the Kruskal-Wallis test. Questionnaires were used to evaluate student and facilitator perceptions.

Results: Students in the digital groups exhibited better performance in the practice procedures according to tutorial evaluations compared with the other groups ($P < .05$). The 2 PBL classes had significantly higher mean results of theoretical and case analysis examinations ($P < .001$), but there was no significant difference between the 2 PBL classes. Ninety-three percent of students in the digital groups (vs 73% in the paper groups) noted that the cases greatly stimulated their interest.

Conclusions: Introducing PBL into ophthalmology could improve educational quality and effectiveness. Digital PBL cases stimulate interest and motivate students to further improve diagnosis and problem-handling skills.

Arch Ophthalmol. 2009;127(9):1211-1214

Problem-based learning (PBL) was first introduced into health care education in the 1960s at McMaster University. Since then, PBL has been extensively implemented in various medical curricula. It was introduced in China in the 1980s. PBL has been extensively applied to basic and clinical medical courses. Problem-based learning is defined as a student-centered, small-group tutorial in which students work through health care scenarios. The main purpose of PBL is to provide a motivating and enjoyable approach toward medical education that promotes the development of lifelong habits of self-directed learning. The process begins with the discussion of a case or scenario directed by the content of the curriculum. The discussion by students generates a hypothesis that motivates further learning. After a period of independent, self-directed study, the students meet to share and discuss the issues about which they are learning, under the supervision of the facilitator.

The elements of the case serve as triggers for student-developed learning issues. The nature of student learning in PBL, to a large extent, depends on the quality of the case presented to the student. Good cases have been described by Westerg as being “real and ill-structured.” The case should be regarded by the students as being relevant to their profession and to real-world clinical situations: these qualities engage student interest. In this respect, it is surprising that so little research has been performed to investigate features that characterize effective cases. The intent of this article is to assess the effectiveness of a case presented in digital vs paper form that uses descriptive PBL in an ophthalmology course.

Methods

The comparison was performed among 90 students in a 3-year clinical medicine program. They were randomly divided into 3 classes, each consisting of 30 students. The first class was identified as the “conventional teaching” class and studied ophthalmology under a didactic model. The other 2 classes were divided into 6 groups total, each consisting of 10 students, and were identified as the “accomplished teaching” group, meaning that they received PBL teaching. Three of these groups studied cases in digital format to fulfill the curricula, and the other 3 were given paper-based descriptions of cases toward the
same end. Of the 24 hours dedicated to the ophthalmology curriculum, 6 hours were devoted to lectures about the anatomy and embryological development of the eye, ophthalmologic examination, low vision, and blindness. Eighteen hours were devoted to PBL modules regarding the conjunctiva, cornea, lens, glaucoma, uveitis, retina, strabismus, refraction, orbit, and ocular disorders associated with systemic diseases.

All teaching processes were accomplished by the same teaching faculty. The PBL problems presented through 4 cases were discussed and set by the faculty. The cases were designed not to convey a definite diagnosis but to present a complex situation and to elicit sequencing problems. For example, a case called “Impulsive Uncle Lee” started with a patient in the clinic with hypertension and a bleeding eye but without significant impairment of sight, followed by acute vision loss 1 month later. Table 1 provides the curriculum content covered by the 4 cases. Initially, the cases were outlined according to their description in the literature but, later, the corresponding clinical data were collected and recorded. Simulated patient scenarios were developed that included but were not limited to the signs and symptoms of ophthalmic patients. Amateur actors (medical graduate students and clinical staff) presented the simulated patient scenarios. The results and procedures for the physical examination, ophthalmologic examination, laboratory tests, and assistant examination were recorded by means of video and photography. All fragments were edited to create different digital cases. Each case was divided into 6 phases: (1) patient encounter; (2) illness presentation; (3) review of body systems; (4) personal, familial, and social background; (5) physical examination; and (6) laboratory findings and other diagnostic procedures. Fragments were presented to the students in succession, and new learning issues were generated. The PBL faculty members switched from their traditional role of “teacher-instructor” to that of “facilitator of learning.” The digital and paper-based cases were brought to the separate groups as learning objectives and those cases triggered extensive discussion and exploration. Students in the PBL course used a wide range of resources, including journal articles, textbooks, educational Web sites, and multimedia CD-ROMs to analyze the problem presented by the case and to identify its critical contents. Each member of the group was encouraged to play an active role in this self-directed learning process. Self-evaluations and peer evaluations were performed during the entire process. The tutorial sessions lasted 2 hours, took place twice a week, and consisted of the following steps: (1) information obtained from the case simulation, (2) generation of an explanatory hypothesis based on abnormal findings, (3) identification of relevant learning issues, (4) an independent study period, and (5) review of learning issues obtained from the consultation of reference resources.

Theoretical and case analysis examinations were performed by the end of the course. The results were analyzed using the χ² test. Student performances in the interval practice of the Department of Ophthalmology were also evaluated. Questionnaires focused on the identification of the strengths of each teaching method based on the assumptions of each proponent, the achievement of specific learning objectives, general curricular questions, and overall preference for each teaching method. The general curricular questions were assessed on a 5-point Likert scale to allow learners to have a neutral choice if they had no strong preference about the question.

### Table 1. Brief Description of Cases Used in the Problem-Based Learning Classes

<table>
<thead>
<tr>
<th>Outline of Cases</th>
<th>Learning Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red eye in a patient with myopia wearing contact lenses</td>
<td>Conjunctiva, cornea, refraction, retina</td>
</tr>
<tr>
<td>Acute onset of ocular pain in a patient</td>
<td>Glaucoma, cataract, retina, uveitis</td>
</tr>
<tr>
<td>Eye bleeding in a patient with hypertension</td>
<td>Orbit trauma, retina, ocular disorders, eye injury associated with systemic diseases</td>
</tr>
<tr>
<td>Strabismus in a patient with cranial tumor</td>
<td>Strabismus, neuro-ophthalmology</td>
</tr>
</tbody>
</table>

Final examination results of the 90 students were analyzed. Full marks on the theoretical and case analysis examinations are 100 and 25, respectively. General student performance during the interval practice was evaluated by their teachers, with rankings from high to low by scales of 5. Table 2 summarizes the test results from the comparison of the theoretical and case analysis examinations for the conventional teaching class and the 2 PBL classes that used digital and paper-based cases. Compared with the conventional class, the mean theoretical test results of the 2 PBL classes were significantly higher (P < .001), but there was no significant difference (P = .86) between the 2 PBL classes. The results of the case analysis examination reflected the same trends as those found in the theoretical examination. The grades given to students in the interval practice of the digital case groups were much better than those of the other groups (P < .001). Of the 90 students who participated in this study, satisfaction with their teaching model was greater in the PBL group using either digital (93%, 28 of 30) or paper-based (90%, 27 of 30) cases than in their counterparts in the conventional group (67%, 20 of 30).

Although 57% (17 of 30) of students in the digital case group felt that they achieved complete understanding of the curriculum content after PBL, and 63% (19 of 30) in the paper case group also felt they achieved complete understanding, 93% (28 of 30) of students in the digital case group stated that the cases stimulated their interest, a percentage that was much higher than that of the paper case group (73%, 22 of 30). Table 3 lists parts of the questionnaire. Students who expressed dissatisfaction with the PBL model explained that, although they were interested in this teaching model, the self-education process took too long to complete and they were not accustomed to the style. Students in the digital groups showed better performance in practice procedures according to evaluations from the tutorial questionnaires. It was easier to adapt their role from student to physician, and they were more active in expressing their opinions during case discussion and learned the ophthalmic examination in a shorter amount of time.

### RESULTS

#### Why should PBL cases be presented in digital form? Usually PBL faculties give students paper-based descriptive cases. Cases are the starting point for student learning activities in PBL. A case usually consists of a description of a phenomenon that requires scientific explanation. The...
nature of student learning in PBL, to a large extent, depends on the quality of the case presented. It is shown that the variability of functioning in small-group tutorials and time spent on individual study were determined by the quality of the cases used.11,15 The question of how we should design effective cases is the starting point of our research. Experienced faculty outlined 7 principles for effective case design and presentation16: (1) the contents of a case should adapt well to the previous knowledge held by students, (2) a case should contain several cues that stimulate students to elaborate, (3) the facilitator should try to present a case in a context that is relevant to the future professional lives of students, (4) the facilitator should present relevant basic science concepts in the context of a clinical problem to encourage integration of knowledge, (5) a case should stimulate self-directed learning by encouraging students to develop a learning attitude and to conduct themselves in such a way that they show no fear of exploration, (6) a case should provoke the interest of students in the subject matter, and (7) a case should match the objectives of the faculty.

One of the prominent features of ophthalmology is that the disease does he or she truly know what keratic precipitate or Tyndall syndrome looked like. Only when the student witnesses the disease does he or she truly know what keratic precipitate or Tyndall syndrome is and, on the next encounter with these conditions, the student will require less time to come to a correct diagnosis. Students in the conventional group and the paper-based PBL group also reported that they received descriptive information about visual field deficits (tubular vision) but, when they were reading the report of the visual field test, they did not display correct judgment owning to the variability of test results. All of these instances indicate that descriptive information is far from being sufficient as a sole means of clinical education17; we need to receive more information through our senses. Therefore, objective teaching is necessary in medical education. Many investigations have indicated that actual patients introduced in the PBL course significantly stimulated the interest and enthusiasm of students. Therefore, objective teaching is necessary in medical education.

We performed this study taking the above-mentioned problems into consideration. Simulated patient scenarios were developed that included the signs and symptoms of a variety of ophthalmic conditions. Amateur actors (of the same type as was mentioned earlier) were recruited to present simulated patient scenarios. The process and results of physical examination, ophthalmology examination, laboratory tests, and assistant examination were also recorded by means of video and photography. All fragments were edited to form

Table 2. Comparison of the 3 Classes Regarding Learning Effectiveness Measured in Terms of the Performance and Satisfaction of Students

<table>
<thead>
<tr>
<th></th>
<th>Conventional Class (n=30)</th>
<th>Digital Cases (n=30)</th>
<th>Paper Cases (n=30)</th>
<th>F Value</th>
<th>H Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theoretical test score, mean (SD)(^a)</td>
<td>74.87 (6.30)(^b)</td>
<td>81.50 (4.08)</td>
<td>81.27 (5.52)</td>
<td>14.68</td>
<td>NA</td>
</tr>
<tr>
<td>Case analysis test score, mean (SD)(^a)</td>
<td>6.97 (0.85)(^b)</td>
<td>13.13 (0.02)</td>
<td>12.63 (5.81)</td>
<td>9.024</td>
<td>NA</td>
</tr>
<tr>
<td>Grade of interval practice, mean (SD)(^c)</td>
<td>3.73 (1.01)</td>
<td>4.33 (0.71)(^d)</td>
<td>3.63 (0.93)</td>
<td>NA</td>
<td>11.63</td>
</tr>
<tr>
<td>The overall satisfaction of students with the course, mean (SD) (scale 1-5)(^c)</td>
<td>3.80 (0.66)(^d)</td>
<td>4.66 (0.66)</td>
<td>4.50 (0.63)</td>
<td>NA</td>
<td>20.38</td>
</tr>
</tbody>
</table>

Abbreviations: NA, not applicable; PBL, problem-based learning.
\(^a\) Analyzed by means of the \(\chi^2\) test.
\(^b\) \(P<.001\).
\(^c\) Analyzed by means of the Kruskal-Wallis test.
\(^d\) \(P<.05\).

Table 3. Parts of the Questionnaire: Opinions of Students Regarding the Effectiveness of the 2 Problem-Based Learning Styles

<table>
<thead>
<tr>
<th></th>
<th>Students Using Digital (Paper-Based) Cases, No.</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases were well designed</td>
<td>20 (22)</td>
<td>8 (7)</td>
<td>2 (1)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Cases kept me engaged</td>
<td>21 (21)</td>
<td>8 (9)</td>
<td>1 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Cases are useful to learning</td>
<td>21 (19)</td>
<td>9 (11)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Cases stimulated my interest</td>
<td>28 (22)</td>
<td>1 (8)</td>
<td>2 (1)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>The learning method helped us achieve our goals for self-directed learning</td>
<td>26 (24)</td>
<td>2 (5)</td>
<td>2 (1)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>The learning method was effective</td>
<td>19 (21)</td>
<td>8 (5)</td>
<td>2 (2)</td>
<td>1 (2)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>I achieved complete understanding of the curriculum</td>
<td>17 (19)</td>
<td>10 (8)</td>
<td>3 (2)</td>
<td>0 (1)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>I would like to repeat the experience</td>
<td>25 (24)</td>
<td>4 (3)</td>
<td>1 (2)</td>
<td>0 (1)</td>
<td>0 (0)</td>
<td></td>
</tr>
</tbody>
</table>
different digital cases. Simulated scenarios of the development of illness, its outcome, and even the possible conflicts between patients and medical staff were also successfully presented. All these attempts to mimic an actual clinical problem made the experience more realistic for students.

This study had strong positive feedback from the students who participated in the PBL course. The test results of the theoretical and case analysis examinations of students in the PBL groups were much better than those of students in the conventional group. Although there was lack of a statistically significant difference between the PBL groups (digital vs paper-based cases), the students in the digital PBL group showed more enthusiasm and better performance during the practice process according to evaluations by their teachers. In addition, those students also felt better about the adaptation of their learnings to clinical work; they were more active when expressing their opinions during case discussions and were fast learners of the ophthalmic examination. These data prove that the introduction of PBL into ophthalmology training programs could improve the quality and effectiveness of the education provided. The PBL cases presented in digital form could stimulate student interest in the further extension and improvement of diagnosis and clinical problem-handling skills. In many investigations, PBL did not show improved learning outcomes compared with traditional curricula, results that were different from those we found. We postulated that the reason for the difference derived from the nature of the course. Ophthalmology is a subsidiary course in the medical curriculum system. Usually students put less energy and effort into the study of ophthalmology compared to other subjects. As students noted their increased interest as a result of having PBL cases, they spent more time working on ophthalmology, and their test scores were greatly improved.

A great challenge for ophthalmology in medical school education is that PBL was rarely applied in the ophthalmology curriculum in Chinese medical colleges until recently. Reasons include: (1) ophthalmology is usually a subsidiary course, (2) the schedule is tight, (3) there is perceived to be too much content to convey, and (4) ophthalmology is more complicated and less easy for students of general medicine to grasp compared with other medical specialty areas. We found limitations when we presented the PBL course in ophthalmology. It consumed much time, funding, and labor. The curriculum schedule was tight. Since 2007, with the enrollment of undergraduate medical students in The Fourth Affiliated Hospital of China Medical University (Department of Ophthalmology), the curriculum has been adjusted to incorporate combined PBL and conventional teaching methods.

In summary, PBL provokes deeper learning by its ability to help students transform experience and understand processes and interactions, rather than gaining a mere surface-level education of facts in isolation. This is especially true when digital cases are used. It fulfills the ideas of the constructivist by the activation of previous knowledge and the building upon of existing cognitive frameworks. The general skills of students improved along with their communication skills, which are responsible for learning and critical thinking. All these skills promote lifelong professional growth as the medical careers of students mature.

Submitted for Publication: October 16, 2008; final revision received January 4, 2009; accepted January 9, 2009.

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Financial Disclosure: None reported.

Funding/Support: This study was supported by grant 03-793 from the China Medical Board of New York and by the North China Center for Medical Education Development.

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