Implementation of Problem-Based Learning in a Baccalaureate Dental Hygiene Program

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Abstract: Problem-based learning (PBL) is an instructional method that is gaining popularity in health care education. Rationale for the use of PBL to better prepare health care providers for the future is provided. Implementation of a PBL model into a baccalaureate dental hygiene degree program is described, including examples of activities that may be helpful to others wishing to implement PBL. Preliminary evaluation results indicate positive outcomes in the intended areas of problem solving and critical thinking, team skills, and personal growth.

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Oral health care providers can no longer rely on facts and information learned in school to prepare them for future practice; before they even graduate, new diseases, medications, and products will appear. The American Dental Education Association Commission on Change and Innovation suggests that emerging science, technology, and disease patterns will change oral health care delivery significantly, creating a "compelling need" to rethink dental education.[1] Students will require more than memorization skills; they will need to know how to learn, how to think, how to make decisions, and how to apply knowledge and experience in a variety of contexts. Skills such as team performance, the ability to listen and communicate, the willingness and ability to learn throughout life, and the capacity to think critically, evaluate situations, solve problems, and make decisions are often identified by dental and other employers as desirable skills for employees.[1-3]

Evolving needs of health care delivery have led to new educational approaches that foster reasoning from evidence, improve thinking, and "create levels of curiosity and skills in inquiry."[1] One approach that is gaining popularity is problem-based learning (PBL), an instructional method that may better prepare students for the role of a working professional than traditional approaches to learning that encourage memorization and recitation.

Problem-Based Learning

PBL, a pedagogical method centered on the solving of real-life problems, is a suitable method for students with varying learning styles, at various levels, and from various cultural contexts.[4-7] According to Barrows, essential components of PBL include real ill-structured problems (ones that may not have "correct" answers), small group collaboration, self-directed learning, and tutors that serve as facilitators rather than content experts.[8] Problems are often descriptions of observable phenomena; for example, "a seventeen-year-old presents with jaw pain and facial asymmetry." Much of the learning is self-directed as students identify their learning goals, or what they need to know to understand the causes of the phenomenon, and complete necessary research to learn the material and develop and analyze solutions. Learning also occurs in a social context when students come together in small groups to share their representation and negotiate differences. In addition to learning content, students learn process skills including how to solve problems, ask questions, find information, communicate, work collaboratively with others, make decisions, and present and support their ideas.

Theoretical Bases for PBL

Essential components of PBL, such as context similarity, activation of prior knowledge, elabora-

tion, and collaboration through group discussion, have the potential to improve learning. Cognitive psychology suggests several ways PBL may actually enhance learning compared to traditional approaches, including the improvement of memory, acquisition of knowledge, and information utilization.[9-14]

Memory, or the acquisition of factual knowledge, may be improved when information is learned in the context in which it will be used.[9] The context of learning in PBL, i.e., related to health problems, is similar to the way the information will be used by practitioners in the future. This matching of context has been shown to improve recall and transfer of learning to new situations that are similar to the way the information was originally learned.

Other research[12-14] suggests that the information-processing theory is a stronger argument for the superiority of PBL than the contextual learning argument. This theory suggests that activation of prior knowledge and elaboration of knowledge at the time of learning may facilitate processing of new information, enhance subsequent retrieval, and improve recall. Initial small group discussions in PBL activate prior knowledge.[14] This, in turn, may have an effect on the processing of new information and what the students will subsequently learn. Elaboration through discussion, answering questions, and attempting to understand problems in PBL may enhance the ability to remember, retrieve, and use the information learned.

Collaborative learning is another instructional method that provides support for PBL. In collaborative learning, students work together toward a common goal and share responsibility for learning. Collaborative learning encourages the constructing of knowledge that can lead to deeper learning or understanding than pedagogies that focus on content, memorization of facts, and passing of exams. The social aspect of sharing and negotiation of individual constructions of knowledge in the small group is central to the PBL approach to learning. Problems are best if they are unsolvable or where there may be "a number of individually constructed knowledge representations that are equally valid."[15] Much of the learning occurs when students discuss inconsistencies and negotiate differences. Alternative views enable the learner to test his or her understanding and build new ideas or solutions that are compatible.[16] These theoretical bases lead us to believe that PBL can provide an advantage over more conventional approaches to education and, particularly, preparation of professionals, through such mechanisms as context similarity, information processing through activation of prior knowledge, and elaboration and collaboration through group discussion.

Implementation of a PBL Model

After visiting several university settings to observe and learn about various PBL models and after much deliberation, participants in this project designed a PBL model for the baccalaureate dental hygiene (B.D.H.) program. Objectives of the PBL curriculum included the following: 1) improve student ability to work effectively in teams; 2) encourage problem solving, critical thinking, and lifelong learning; and 3) foster personal growth and confidence. It was not expected that these objectives would be mastered in one or two courses, but rather would pervade throughout the curriculum.

I consulted literature on problem-based learning,[17] clinical reasoning,[18] problem solving,[19] reflective judgment,[20,21] and cognitive apprenticeship[22] to construct a series of problem-solving steps. A mnemonic of the steps was crafted to lower the initial cognitive load and to help students better remember the steps when transferring to new problem-solving settings.[23] The steps, spelling out INFORMED, were as follows: I—Issues and Information known; N—Need to know; F—Find information; O—teach and learn from Others; R—Recycle, Reflect, identify Real problem; M—Make list of solutions; E—Evaluate solutions; D—Decide, Deliver, and Debrief. (See Table 1 for more detailed description of the INFORMED steps.)

In preparation for PBL, faculty tutors attended a tutor training session and an orientation to the INFORMED process, specific problems, and goals for the course. Tutors received a resource manual containing reference materials, learning issues, questions and tools to encourage thinking, and concept maps for each problem. Once PBL was implemented, weekly tutor meetings were held immediately after each class session to discuss issues, needs, and future directions.

Sixty-seven students have completed the PBL course—forty-five in the spring of 2006 and twenty-two in the fall of 2006. Implementation for students consisted of an initial orientation to the PBL process followed by a succession of problem-solving sessions. Students met face to face once a week for two hours in groups of five to six with a faculty tutor, with one hour allocated for work outside of class. After approximately seven weeks of orientation, students

Table 1. The INFORMED problem-solving process

I	INFORMATION/ISSUES/IDEAS. Discuss ideas and hypotheses about the issues. Determine what is known and how it is known.
N	NEED. Determine what information is needed (learning issues) to progress with solving the problem.
F	FIND. Find good sources for information needed (e.g., discuss whom to talk with, what search strategy to use, which sources are best).
O	OTHERS. After learning the information independently, students share it with others in their group, comparing findings and discussing various perspectives.
R	REAL/RECYCLE/REFLECT. State the real problem in clear, simple terms. Be sure you are solving the right problem. Clinical cases may unfold with additional information, requiring a recycling through the previous steps. Reflect and recycle through the steps until the real problem is identified.
M	MAKE. Make a list of all the possible solutions or hypotheses.
E	EVALUATE. Evaluate each potential solution or hypothesis, considering reasons for or against, consequences, supporting and conflicting evidence, and quality of the evidence.
D	DECIDE/DELIVER/DEBRIEF. Deliver the solution determined to be best in an appropriate format to the appropriate audience. Debrief including self-, peer, and tutor assessment.

worked in groups to solve two to three problems, averaging three to four weeks for each problem. Each week students wrote about their experience in a reflective journal.

Orienting students to the PBL approach is a critical step in the process of integrating this strategy into the curriculum. Because some students think they are already sophisticated problem solvers, the groups first analyzed a simple problem ("Sonia"; see Table 2) without any assistance from tutors and prior to any discussion of problem-solving strategy.

Table 2. List of problems used in PBL training

SONIA	Sonia is a fellow classmate who is cheating, and it is affecting your grade.
MARY	Mary is a student who is unhappy because her group is not cooperating, and she worries it will affect her grade. Students assume the role of a teacher.
DONNA	Donna, a clinic manager, must determine which pre-rinse is best to use in the clinic.
VIRGINIA	Virginia has an oral lesion that becomes serious (cancer).
MAGGIE	Maggie has NUG, and during treatment the clinician experiences a needlestick.
ALLEXA	Allexa and her employer differ dramatically regarding standard of care.
THOMAS	Thomas is suing the clinic (students, in the role of a lawyer, must determine if there is enough evidence to win the case).
LORENA	Lorena has dental anxiety, rampant caries, and impacted third molars that become problematic.

Next, the INFORMED model for solving problems was introduced through direct instruction (see Table 1). After introducing the model, students applied the steps to the same problem they solved initially ("Sonia"). Each step was taught separately, and working examples were created as a class.[24] Students compared the new strategy to the approach they used initially, before learning the INFORMED process, to help them see more clearly the mental processing involved in the strategy.[25]

Next a problem ("Mary"; see Table 2) was introduced, which acknowledges students' prior negative experiences with group work. "Mary" is unhappy because her group is not cooperating and she worries it will affect her grade. Students were placed in the role of a teacher who wants students to learn team skills and enjoy working in groups. Students applied the steps again in groups, using worksheets to guide their process. At this early stage of gaining familiarity with the PBL process, the use of worksheets helps students translate abstract problem solving into a manageable process. Worksheets were available for guidance through each step in the INFORMED process, but were not required once students gained basic proficiency. The tutor's role was to help the group balance between not enough and too much structure to encourage interaction without hindering thinking. Participants learned and practiced principles of giving and receiving feedback graciously by writing five "good things" and two "things to improve" for their group as a whole.

After working through the steps twice with simple scenarios, a problem emphasizing location

and utilization of research evidence ("Donna" must decide which pre-rinse is best for use in the clinic) was introduced. Students met in the computer lab to practice search strategies for quickly finding relevant high quality evidence using PubMed and advanced Google searching. Students located and shared the information with their group, discussed differences, weighed pros and cons, and made and delivered a decision.

Effective teamwork requires training in how to work in teams,[26] so time was spent understanding individual differences and developing skill in communication, group dynamics, leadership, and decision making. Once students understood the INFORMED steps, they were introduced to specific group roles that they used to determine group rules. Six roles, identified through experience and readings,[27] were rotated each week to help students develop a variety of vital skills (see Table 3). Students completed and shared results of inventories, such as Myers-Briggs[28] and conflict management style,[29] to gain self-awareness and appreciation of differences and the implications for working as a team. A decision-making exercise was introduced to help students understand that working together usually results in a higher quality product. Students individually prioritized various items in a survival scenario (e.g., stranded on Mars[30] or in a bush fire, Human Synergistics®) and then prioritized the items as a team, using consensus. Comparing individual and team rankings with expert rankings helped students see the advantage when all team members participate. This exercise is valuable because students often get impatient with the amount of time it takes for work to be accomplished in groups.

After the orientation, students were eager to begin working through dental hygiene-related problems (see Table 4 for a summary of orientation activities). Problems, written to successfully drive learning of desired content, were introduced with a hook[17] (e.g., a video clip or a dramatic enactment) if the problem was complex in nature, such as a legal or ethical dilemma, or with a description of a patient scenario if the problem was clinical in nature. Details of the problems, or cases, were revealed in stages. Students discussed the case as a group and responded to a set

Table 3. Roles used in learning to work as a team

SCRIBE	Records and organizes information on white board or large paper pad; lists learning issues.
CHAIR	Directs, delegates, and leads the process to the desired result.
ASKER	Facilitates thinking by asking questions (e.g., "Why is that piece of information needed?" "How sure are you?" "How is that related to the problem?").
REPORTER	Summarizes information and posts to the online discussion section so all have access (e.g., hypotheses, solutions, alternatives, pros and cons).
TASK MANAGER	Periodically summarizes progress with the task; keeps the group moving through the steps at the appropriate time, suggesting the use of worksheets when appropriate.
ENCOURAGER	Encourages all to participate. Provides feedback to others in the group.

Table 4. Sequence of PBL orientation activities

Week 1	Sonia problem.
Week 2	Introduction to PBL and INFORMED steps. The class applies each step to the Sonia case, resulting in a worked example.
Week 3	Information is provided on teaching (O step) and giving feedback (D step); INFORMED steps are repeated on a new problem (Mary, with reference materials provided for F step); practice giving feedback to group.
Week 4	Introduce students to PubMed and advanced Internet searching; new problem (Donna) emphasizes finding and using information (F, E, D steps).
Week 5	Students teach each other and decide which rinse to recommend; practice providing individual feedback; entire class debrief.
Week 6	Introduce roles; teams decide rules and share results from inventories; discuss implications for the group.
Week 7	Decision-making exercise.
Begin multistaged dental hygiene problems.	

of questions that accompanied the case. For example, they were asked to choose a course of action or prioritize their concerns. Progressively more information was distributed, a page at a time, when students were ready to move ahead. The cases were multidimensional, usually including cultural, socioeconomic, or psychological dimensions. Students were encouraged to integrate basic and clinical science, share their thought process, and explain suspected underlying connections. The students discussed what was known about the case and generated preliminary hypotheses about suspected underlying phenomena. They determined what additional information was needed and where they would find it and then set about to locate high quality and relevant data. Upon returning to the group, students shared what they had learned with their team members. At this time they negotiated differences (learning occurred) and revisited their initial hypothesis or decision (built on prior knowledge) to see how it had changed with the new information. Once the group identified what they considered to be the real problem, students brainstormed possible solutions, evaluated the strength of each potential solution, and, finally, made a decision. When they had accomplished these tasks, the group received the next stage of the problem, and the process began again. A debriefing session was held in small groups at the end of each day and in the large group after each problem. There are no right or wrong answers in a good PBL problem; however, a list of references, an achievement test over intended content, and a concept map (a series of circles, lines, and arrows connecting problem components with intended learning issues) were utilized for the purpose of providing feedback and facilitating learning.

Three to four weeks were spent working through the first problem ("Virginia" has an oral lesion that turns out to be serious). After completion of the first problem, all students and tutors held a combined debriefing session. Tutors then rotated to a new group. This rotation allowed groups to experience tutors with varying perspectives and a range of experience, knowledge, and skill—areas identified as critical to tutorial group success.[31-36] Tutors also had the opportunity to see how differently each group functions.

The next problems were worked through with less tutor guidance and at a pace dependent upon learning issues for each group. Students continued to apply the problem-solving process to problems similar in context to real world problems they will encounter in practice. To increase "representation of the problem" and schema construction, which are important for construction of learning or development of deeper understanding, students were encouraged to diagram the process relative to the problem using a flow sheet and/or a concept map.[24] Tutors monitored the students' evolving understandings, responding with cues, prompts, analogies, and other forms of assistance as needed. Initially tutors provided more assistance and then faded[37] or gradually reduced the level of assistance until students could complete the problem-solving process without prompting.[25]

Problem scenarios are designed relative to perceived needs identified by students and faculty. The closer the problem scenarios are to the students' needs, the better the response. To determine the learners' needs, faculty looked for areas of weakness in performance in clinic and other courses, so problem scenarios would be relevant and timely. A variety of specific problems have been introduced with some content intended to be learned but still open for student direction. Table 2 provides a synopsis of the cases used in this PBL course. The "Maggie" case involves a patient who has NUG, for example, and a needlestick occurs during treatment, while in the "Virginia" case, the patient has an oral lesion that becomes serious and evolves to cancer.

A formative evaluation continues to provide information useful for improvement and understanding effects of the PBL component of the curriculum. The question of most interest to the B.D.H. program is not whether PBL is better than traditional approaches to learning but rather to what extent PBL can affect process skills related to critical thinking, problem solving, lifelong learning, teamwork, and personal growth. The evaluation includes students and faculty as sources of information and utilizes a variety of methods including interviews, researcher-designed questionnaires, tutor and faculty focus groups, observation, content analysis of journal writings, inventory scores, and measures of learning outcomes. Results in this preliminary report are primarily from faculty and tutor focus groups, observation of tutorials, student journals, and student questionnaire responses. Informed consent and IRB approval were obtained. Code names were used for journal entries and on student questionnaires. Qualitative and quantitative data were collected with open-ended questions asked to gain insight and depth of understanding. Findings in this report are based on findings from the most recent offering of the course, which involved twenty-two students in fall 2006, their junior year in the B.D.H. program. This student group was 23 percent

culturally diverse and included two males and twenty females, with ages ranging from the early twenties to late thirties.

Results

Preliminary evaluation results indicate positive outcomes in the intended areas of problem solving, critical thinking, lifelong learning, team skills, and personal growth.

Problem Solving

Students rated solving problems as the most beneficial activity in the course (see Table 5). Most students gained skills and enjoyed learning a problem-solving process; others found the INFORMED steps confining. One said, for example, "The first day ["Sonia" problem] we clumped the steps together and did not discuss the pros and cons. The INFORMED process helps us be more organized and thorough."

Some students felt they were already good problem solvers prior to the course; most faculty and tutors disagreed that students already knew how to solve problems effectively. Tutors commented on students' novice tendency to focus on surface features of problems rather than on the underlying problem source as expert problem solvers do.[2] For example, in the "Virginia" case (see Table 1), students sometimes ignored the specific characteristics of the patient's swollen glands, assuming they were related to her recent cold rather than the oral lesion.

Tutors also indicated that students demonstrated the novice tendency toward premature closure and stubborn support of poor decisions. For example, in the "Virginia" case, students sometimes decided to use a screening tool without understanding how it works (e.g., what makes some cells take up more dye or light than others?), without investigating whether there were better screening tools (e.g., is a brush biopsy the only choice?), without awareness of limitations of the information provided (e.g., what could cause a false positive result?), and without understanding the purpose (e.g., to rule out a lesion you don't suspect vs. confirm a suspicious lesion). Expert problem solvers review the options before selecting the best course of action based on pertinent information.[2] Students sometimes ignored or failed to recognize important data (e.g., focus on periodontal treatment of a healthy, well-maintained patient rather than focus on a more serious oral lesion). Development of problem-solving skills is an ongoing challenge. PBL provides students with important practice and feedback and encourages movement from novice to competent and expert reasoning.

Critical Thinking

Critical thinking is a difficult concept to define and measure.[38-41] The B.D.H. program considers open-mindedness and the fair consideration of various perspectives to be important components of critical thinking. Students reported feeling confident listening with an open mind to different ideas (mean=8.9, SD=1.1; scale 1=not confident to 10=very confident). One student reported:

> "PBL has taken my learning to a deeper level. I like to hear others' ideas and rationales. Before this class I was closed minded. I thought my answer was right. Now I think about . . . solutions I didn't originally think of—and sometimes they are better than mine."

Throughout the PBL course, students had the opportunity to listen to various viewpoints, which led to their growing awareness of differences. After the survival decision-making exercise, a student wrote:

> "Different things are important to different people, depending on their perspective. In the fire scenario, those who considered escaping chose different items from those who planned to stay to protect the house."

Other important aspects of critical thinking are asking questions, making connections between new and prior knowledge, generating solutions, analyz-

Table 5. Students' rating of PBL activities

Rate the amount you benefited from each of the following course activities:	Mean (Standard Deviation)*
Solving problems	4.0 (0.8)
Decision-making survival activity	3.5 (1.0)
Receiving feedback from peers	3.5 (1.2)
Providing feedback to peers	3.0 (1.2)
Use of roles in the group	2.8 (1.0)

n=22
*Likert-type scale from 1=not beneficial to 5=very beneficial.

ing arguments, and making and justifying decisions based on evidence. Student and tutor comments indicated progress in these areas. Scores from pre- and post-questionnaires were compared for significance using a paired t-test. Students indicated their level of confidence in specific areas on a ten-point scale ranging from 1=not confident to 10=very confident. Scores showed no significant difference in students' confidence asking appropriate questions (see Table 6). Questioning was an area identified by tutors as needing further development even though comments showed some progress in this area:

> "Another pretty big thing that PBL taught me is to ask why? . . . If you do not know the answer to 'why?,' you need to do more research!" (Student comment)

> "I saw [the students] grow in their ability to think. At the end they were starting to question each other rather than just accept things." (Tutor comment)

The difference between pre and post scores in "making connections between new and prior knowledge" was significant (see Table 6). Students reported, for example, being able to "sift through articles to determine the relevant and non-relevant information to our specific case." Students also felt more confident in their ability to justify a position and support a statement with specific examples after PBL (see Table 6). For example, one student reported:

> "Some thought tobacco use was most important, others thought the lesion/lymph node enlargement was most important. Discussing the rationale . . . changed our minds."

Another student identified a need for improvement in this area:

> "If somebody . . . sounds like they know what they are talking about, my group will take that route. We need to work on not being so easily persuaded. . . . we decided to give reasons why."

Students did not feel significantly more confident in their ability to analyze arguments (see Table 6). One student reported: "My group needs to work on exploring opposing opinions before deciding which route to take." However, students' confidence in their ability to make valid conclusions based on evidence increased significantly (see Table 6). The PBL process encourages students to identify and find information sources and critique, interpret, and cite literature. Students and tutors agreed there is a lot of room for improvement in this area. Said one student: "Even when we read the same article, we came up with completely different things."

The PBL course is currently offered to students prior to a course that teaches interpretation of scientific literature. Consequently, sequencing of the curriculum is under consideration to determine the ideal arrangement of courses.

Lifelong Learning

Lifelong learning and self-directed learning skills including the ability of students to determine their own learning goals, locate appropriate resources, and assume responsibility for learning what they need to know are long-term goals of most educational endeavors.[42] Self-directed learning was one of the top areas where students identified skill improvement

Table 6. Student-reported changes in confidence during a problem-based learning course

How confident are you in your ability to:	Before Mean (SD)	After Mean (SD)	Significance
Ask appropriate questions.	7.7 (1.5)	8.0 (1.7)	p=.347
Make connections between new and prior knowledge.	7.0 (1.4)	8.2 (1.4)	p=.004*
Justify and support a position.	6.9 (1.7)	8.0 (1.4)	p<.000*
Analyze arguments.	7.4 (1.8)	7.9 (1.5)	p=.23
Make valid conclusions based on evidence.	7.3 (1.9)	8.5 (1.3)	p=0.011*
Provide constructive feedback to peers.	5.7 (1.8)	7.7 (1.9)	p=.001*
Question an instructor.	5.0 (2.2)	7.9 (1.6)	p<.000*
Assess strengths and areas to work on.	6.0 (2.9)	8.5 (1.1)	p=.001*

n=22
SD=Standard Deviation
*Significant difference, 2-tailed paired t-test

as a result of PBL (see Table 7). Student comments demonstrated success at determining learning issues; for example, "our group is doing great with relevant learning issues. Many of them were answered in the next segment of the case."

Early in the course, students relied heavily on tutors for identification of learning issues. Some groups felt learning issues were "sidetracking" or "distracting" them; they preferred to skip over the difficult areas to "get on" with the problem. One area related to lifelong learning where students felt a significant benefit was learning how to search for appropriate resources. For example:

> "I used to do a Google search and hope for the best. . . . now that I have learned how to do an advanced search . . . and to search PubMed, I . . . look up facts . . . rather than hoping for the best." (Student comment)

Self-directed learning skills and disposition are important for students to acquire or develop to be more responsive to the rapidly changing demands of the workplace.[42]

Team Skills

In addition to gaining problem-solving, critical thinking, and lifelong learning skills, the ability to function as a member of a team is very important to successful work in oral health care settings. Working with others was one of the areas the students enjoyed most about PBL. Skill improvement in teamwork received one of the highest scores when students were asked which areas of personal growth and development they attributed to the PBL course (see Table 7). Student attitudes about working in groups also became more positive as a result of the PBL group experience. As one student said, "I despised group work . . . had never had a good experience. Now I can honestly say I have had a good experience and see how valuable groups can be."

Students also indicated a gain in leadership skills (see Table 7), felt confident making decisions by consensus (mean=9.0, SD=1.1; scale from 0=not confident to 10=confident), and learned to better manage conflict. As one commented, "Conflict isn't just yelling or . . . getting mad. . . . When there is disagreement, it helps to voice your opinion so both parties can understand. . . . Now I handle conflict differently (more healthy) in my relationships outside of school."

One of the most important challenges of building a team is to overcome the hesitation to give each other critical feedback. Triangulated communication is more rampant in dental offices than caries. For example, hygienists think assistants should do something differently, but instead of telling the assistants, they tell everyone in the office *except* the assistants. Failing to provide peers with constructive feedback hurts the team and teammates.[43] Receiving feedback from peers was given one of the highest ratings of benefit (see Table 5). Most students had no trouble telling their peers what they did well. Providing appropriate constructive feedback was more of a struggle, requiring tutor encouragement and modeling. At the beginning of the course, students' confidence was low in this area (see Table 6); however, it showed considerable progress over time. In the words of one student, "I am able to word constructive criticism in a productive way that does not hurt other people's feelings. I still need work, but I have progressed significantly." When asked how confident they felt providing constructive feedback to peers, students attributed a significant increase to the PBL experience (see Table 5). "My biggest improvement is being able to address others directly now," said one.

Use of group roles received one of the lowest ratings of perceived benefit (see Table 5). The roles were simplified halfway through the course and assigned more descriptive names. Some students thought learning roles was valuable and helped organize the group. Other students voiced discontent, primarily because they were frustrated with the difficulty of trying new roles at the same time they were trying to apply a new problem-solving process. Some felt the roles got in the way. One said, "What I liked least was being bound to a role. . . . The scribe role limited my ability to fully contribute . . . because I had to focus on writing."

Table 7. Student self-ratings of skill improvement from a problem-based learning course

How much has your skill in _____ improved as a result of the PBL course?	Mean (Standard Deviation)*
Teamwork	3.5 (0.9)
Leadership	3.5 (0.8)
Self-directed learning	3.4 (0.7)
Self-assessment	3.4 (0.7)

n=22
*Likert-type scale from 1=no improvement to 5=significant improvement.

In spite of the low rating, most students felt confident performing the roles (mean=8.0, SD=1.4; scale from 1=not confident to 10=confident), and comments at the end of the semester suggest that roles provided structure that helped many students gain confidence. One said, "My role gave me a chance to speak up. I became comfortable and did not think twice about speaking, as I had before." Using roles may have helped some students develop skill and confidence by providing a variety of situations where they could experience success. For example, "Roles encourage me to . . . try new things, to leave my comfort zone." Appropriate use of roles also helped facilitate higher functioning groups. In the words of one, "Playing the [asker] role helped us look into other possibilities . . . in other directions . . . that facilitated deeper learning."

Personal Growth

Students assessed their strengths and set goals regularly. The process of setting goals helped students think about what they wanted to achieve and where to focus their efforts. "My goal is to speak up before people ask what I am thinking," said one. "I want to have a stronger voice no matter if I am wrong or right."

By setting goals, students could see their progress and take pride in their growth and personal achievement. When asked how comfortable they were assessing their own strengths and areas to work on, students indicated a significant improvement in this area (see Table 6). Comments indicate increased self-awareness and goal setting. For example, "I was very dominant at first, but I learned to listen more and let others take the leadership role."

By far the most prevalent and encouraging comment from students was that they gained confidence. Several students found confidence in their ability to learn and to have something of worth to share with the group. In other instances, a gain in confidence was linked to receiving feedback or using roles. For example:

> "I thought my ideas were not as good . . . but when asked what I thought, my ideas changed the direction of the group. My self-worth and confidence improved."

> "I was shy speaking and felt [my group] would think I was stupid. Now I know my opinion matters and could be . . . something no one else thought of. . . . My group members allowed me to speak and didn't judge me."

These comments demonstrate that PBL groups provide opportunities for students to practice cooperative interaction in a safe environment.

Learning Transfer

Another goal of PBL was for the students to transfer the learning: to use the problem-solving steps not only in the PBL course but to routinely and automatically and/or consciously apply them when they encounter problems in other settings.[25] Faculty observed students applying the knowledge and skills they learned in PBL to other classes and in the clinic. Comments from students indicated that knowledge learned through the PBL process seemed more personal and real to them than what they learned from lecture or textbooks. Students actually came to identify with the people in the PBL cases and spoke of them as if they were real. Students commented that they could remember the drugs they had learned through the PBL cases better than the ones they had memorized for the didactic course. After the "Virginia" case, faculty reported that students began to perform improved oral inspections, screen oral lesions more often, and were careful to refer and re-evaluate oral lesions. One faculty member commented: "We are seeing carryover into clinic. [Students] were screening lesions right and left and taking pictures." Another faculty member commented that, after the "Thomas" case (see Table 1), students were more careful to document everything and were better prepared for chart audits: "Since the Thomas case, the students understand why we're doing the chart audits. . . . It finally made sense to them . . . not a wasted effort." Communication and teamwork were also reportedly improved in clinic and other courses.

Unanticipated Outcomes

One unexpected and positive outcome of PBL was the impact on the faculty who served as tutors. Tutors indicated that what they learned carried over into other aspects of teaching. Some indicated that they are now more comfortable asking questions rather than giving answers. Others indicated that what they learned about students helped them teach better in the clinical setting. For example:

> "I learned so much about the students in PBL . . . how they think . . . how they pro-

cess, that now I know how to work better with them in clinic."

"One student hardly spoke until coaxed. When she did speak, I realized she was quite a deep thinker. . . . Now I work with her differently."

It became evident to the B.D.H. faculty how essential the tutor role is in PBL and in improving education throughout the program. As a result, one area of focus for the department will be on development of tutor skills.

Discussion

Findings of this preliminary evaluation are highly contextual and limited to one course in one B.D.H. program. The students, the tutors, the quality of the problems, the learning issues, and other components of curriculum design make each program unique. Results of studies of curriculum format may be due to one or a combination of components. It is difficult to determine if differences are due to the PBL approach alone or if there are other variables, such as teacher or tutor experience, small group dynamics, prior knowledge, expertise of students, or other coursework, that are confounding the results of this and other studies. Thus, these findings may not be generalizable to other programs.

The effectiveness of PBL is difficult to evaluate for several reasons. Halpern states that "assessing outcomes that result from critical thinking is fraught with multiple measurement and logistical problems."[39] Many studies on PBL have attempted to answer this question: is PBL working?[9,44-55] One problem is that, with problem-based learning, the emphasis is on learning as a process; however, many researchers and educators use conventional tests that require recall or application of specific facts, such as scores on multiple choice standardized tests, including the National Board Dental Examination, to indicate success. According to Vernon and Blake, "The outcome variables that are often the most highly valued, and best exemplify the special features of PBL, are often complex, multidimensional, and difficult to measure."[44] Quantitative data about knowledge acquisition demonstrated by board exams are not enough to determine if PBL is truly superior. At best, these approaches demonstrate that PBL is not worse than traditional methods in providing students with necessary content.

The question of interest to our B.D.H. program is not whether PBL is better than traditional approaches to learning but rather to what extent PBL can affect problem solving, critical thinking, lifelong learning, teamwork skills, and personal growth. Preliminary results after a one-semester PBL course are encouraging. The early evidence seems to indicate that PBL is beneficial; however, the department will continue to explore and evaluate the implementation of PBL in the curriculum. PBL requires additional faculty resources in the role of tutor, which must be weighed against the faculty and student development benefits.

The real question is this: will students apply what they have learned in their work settings? In addition to the observation of immediate benefits of the PBL experience, there has been evidence of transfer observed in the clinical and other classroom settings. Strategies such as using a mnemonic, teaching component skills for understanding, providing worked examples, having students apply the process to a variety of different problems, and asking students to reflect on and monitor their use of the process have been incorporated into the PBL model to enhance the likelihood of transfer. It is hoped that when students are given new problem situations, in other courses or in practice, they will remember and recognize the need to use what they have learned.

Will students be able to "enter the profession competent to meet the oral health needs of the public throughout the twenty-first century and to function as an important member of an efficient and effective health care team"?[1] It may be years from now that the real answers unfold. The answer to the questions about appropriate educational methods may come with the discovery of which pedagogical approaches were used to prepare the clinicians who are making a difference in the world of health care, the ones who are on the cutting edge, developing solutions to new problems and solving mysteries of diseases that are not found in the textbooks. Studies show that PBL students may be better at acquiring self-directed learning skills while in the program, but will this difference be sustained? Will the self-directed approach to learning in PBL result in practitioners who are more likely to read scientific literature and stay current in their fields?

It is too early to know the answers to these questions. Future attempts will be made to obtain feedback from alumni and employers. One thing seems to be certain: for the development of expertise, the seeds must be sown during the in-school phase of

professional education.[2] The goal of problem-based learning, more sophisticated than simple acquisition of knowledge or skills, is to produce clinicians who can solve real problems, develop new insights, perform in varied contexts, and who will thus be valued in the world. The B.D.H. program is sowing seeds and attempting to provide rich ground and proper conditions for ultimate growth through the PBL program. In the words of one of the tutors: "It is important work we're doing. PBL is like a seed that's germinating. Students' learning about themselves is huge. . . . It might not happen today, but in the future . . . these things will become more meaningful for them."

There is no doubt in the minds of those teaching in the B.D.H. program that PBL is having a positive impact.

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