Problem-Based Learning in the Clinical Laboratory Science Curriculum

Wendy Beadling, MS, MT(ASCP)SBB, and James Vossler, MS, MT(ASCP)SM, CLS(NCA)
From Department of Clinical Laboratory Science, College of Health Professions, State University of New York Upstate Medical University, Syracuse, NY

Introduction
The clinical laboratory is changing at an unprecedented rate. The introduction of new technologies and increased automation along with a reduction in personnel has placed unparalleled demands on laboratory professionals. Increasingly, clinical laboratory practitioners must exhibit broad-based problem-solving skills, independence, flexibility, and a willingness to work collaboratively with other health care professionals.

Educational programs in the clinical laboratory sciences (CLS) face the challenge of preparing graduates with these skills. A curricular approach gaining respect in allied health education is problem-based learning (PBL), which evolved from innovative medical school curricula introduced almost 30 years ago. PBL takes into account how students learn, fostering the development of critical reasoning skills within the context of their professional discipline, as well as the motivation for lifelong learning necessary for adaptation to a changing environment.1

At State University of New York (SUNY) Upstate Medical University (Syracuse, NY), a new course called Clinical Correlations was recently incorporated into the 2+2 bachelor of science curriculum in medical technology. The course uses a PBL format in which students apply critical reasoning, communication, and collaborative skills in a small-group, learner-centered environment. The philosophy underlying PBL is that individuals best develop knowledge and skills by actively solving problems and building conceptual frameworks rather than through the passive memorization of facts. Students explore carefully designed problems that integrate content from across the laboratory disciplines under the guidance of a facilitator who challenges them to an in-depth examination of the case objectives.

Since implementation of this problem-based course, our students demonstrate an increased ability to evaluate information from multiple perspectives, are more comfortable critically questioning their own decisions and conclusions, and show a greater level of responsibility for their own learning.

What Is Problem-Based Learning?
Problem-based learning is an education methodology and philosophy in which a carefully designed, realistic situation containing a problem or series of problems is used to motivate and challenge students to acquire and synthesize the information necessary to evaluate, discuss, and resolve the problem. The premises on which PBL is based involve principles of learning developed by research over the years in the cognitive branch of psychology, including the areas of information processing, developmental psychology, and motivation.2

“Classic” PBL usually focuses on the processes of thinking and problem-solving as well as having the objective of meeting interdisciplinary curricular goals through the use of a particular set of problems.

The hallmark of problem-based courses or curricula is student-centered learning that takes place in a small-group environment, guided by facilitators who do not provide answers, lecture, or impose their direction on the initial inquiry process.3 Instead, case information is provided through progressive disclosure by a facilitator whose job it is to challenge students to explore the case objectives in depth. Students discuss what is known, form hypotheses, research student-identified learning objectives, and communicate their learning to the group in a cyclic process that culminates in the case resolution [F1]. Ultimately, in all PBL methods, students assess their progress through the case in a self-reflective process.

In making the decision to implement PBL either in a single course or in an entire curriculum, a significant amount of planning is involved. Many important issues including choice of content objectives, the increased class time needed to engage in the PBL method, the need for good facilitator training, and development of information and facilitator assessment tools must all be considered. The interested reader is referred to Barrows and Tamblyn,4 Boud and Feletti,5 and Vernon and Blake6 for a comprehensive review of PBL and the factors affecting its implementation.

Problem-Based Learning in the Clinical Laboratory Science Curriculum
The clinical experiences in our 2+2 medical technology (MT) curriculum are arranged in discipline-specific blocks of time. Consequently, our students tend to “compartmentalize” and have difficulty integrating laboratory findings and their corresponding diagnostic
implications from one laboratory discipline to another. Our CLS faculty agreed that PBL not only was useful for developing critical thinking skills, but also was an ideal format in which to present problems that required the student to continually integrate concepts from across different laboratory disciplines to resolve a given case. The faculty decided to shift discipline-specific case-study materials out of the individual clinical rotations to allow for time during the week in which all senior students would meet together to solve such integrated case problems. Our ideas were put into practice during a 2-year pilot study. This activity subsequently made the transition into 2 formal courses, Clinical Correlations I and II, during the 2000 fall and spring semesters.

Currently, students and facilitators in Clinical Correlations I and II meet 1.5 hours per week during the fall and spring semesters. During the first and second class meetings, students and faculty meet as a large group to discuss the goals and processes of PBL so that the students will feel comfortable with what will be a different kind of learning experience. During the second session, students are introduced to a prototype problem by a faculty facilitator with other faculty participating in the group as “students.” The group practices analyzing the problem and recording data. Questions raised by the students that must be answered to understand the problem are restated as objectives, or learning issues. Later in the session, 2 faculty “students” present their investigation of 2 different learning issues pertaining to the case. They use this opportunity to illustrate both good and bad examples of aspects such as organization, communication skills, use of reputable, current resources, and connecting the information from the learning issue back to the case. The students are asked to verbally evaluate the faculty “students” on their content and presentation.

For the remaining classes, students are divided into groups averaging 5 to 7 in number, mixing students from different clinical rotations, so there is a variety of levels of knowledge and clinical experiences represented in the group. Each group receives the same problem, with a different facilitator, who stays with that group throughout the case. Through progressive disclosure, students are provided with the complete case over a 3 to 5-week time period.
The Trouble With CBC Counts

It's lunchtime in the automation section of the core laboratory. A newly hired biology graduate named Jim, who is being trained as a technician, is operating the laboratory's Technicon H*1 automated hematology analyzer under the somewhat watchful eye of his trainer, Christine, who has left the area, telling Jim she'll "be right back." Jim has all he can do to keep up with the STAT CBCs coming from the ER.

Jim is currently reviewing the results of the CBC on a 31-year-old male patient currently in the ER. Dr Wiley, the ER physician, has now called twice asking for the results. Jim looks around for Christine who is nowhere to be found. He looks again at the results, trying to remember the myriad details about CBCs (or was that ABCs?) he had learned from Christine earlier that morning. "My name's going to be mud if I don't get these results out now," he thinks. Jim sends the results to the ER STAT printer at 12:35 PM.

Below is the instrument printout for the CBC and the RBC histogram and cytoagram that Jim was reviewing.

<table>
<thead>
<tr>
<th>CBC Count Results</th>
<th>Reference Range (Adults)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WBC 10⁹/μL</td>
<td>4.0-10.0</td>
</tr>
<tr>
<td>RBC 10⁹/μL</td>
<td>4.6-6.1</td>
</tr>
<tr>
<td>HGB g/dL</td>
<td>13.5-18.0</td>
</tr>
<tr>
<td>HCT %</td>
<td>41-53</td>
</tr>
<tr>
<td>MCV fl</td>
<td>80-96</td>
</tr>
<tr>
<td>MCH pg</td>
<td>27-32</td>
</tr>
<tr>
<td>MCHC %</td>
<td>32-36</td>
</tr>
<tr>
<td>RDW %</td>
<td>11.5-14.5</td>
</tr>
<tr>
<td>PLAT 10⁹/μL</td>
<td>150-400</td>
</tr>
</tbody>
</table>

MORPHOLOGY FLAGS

ANISO +++
MICRO ++
MACRO +
VAR
HYPO
HYPER
L SHIFT +
ATYP
BLASTS +
OTHER

[Fig.] First page of the problem-based learning case that set the scene and presented the initial dilemma in the patient problem, which was elaborated on and discussed over the following 6 weeks.
Case Development and Investigation

To stimulate discussion in a problem-solving framework, the faculty created a bank of cases ranging from simple to complex. As a direct result of feedback from the students in our pilot study, we have tried to create cases that present the problem from the perspective of a practicing MT, rather than from a patient-diagnosis perspective, which is typical of those problems seen in medical school curricula. Aspects of clinical diagnosis and associated pathophysiology are gradually introduced into the problem as the case progresses. The problem may be introduced in a variety of formats from a single paragraph to a more lengthy presentation that sets the scene. Each case is based on a realistic situation that might occur in the clinical laboratory and is divided up at critical points to provide opportunities for further investigation. Cases generally have 1 central theme with threads tied into the focus of the case. The more complex cases to be used during the second semester integrate 2 or more clinical areas, as well as specific laboratory operations issues such as staff competency, scheduling challenges, and method evaluation.

The case author develops the problem around learning objectives that should be identified by the students, incorporating appropriate “cues” in the body of the case that the facilitator can use to stimulate discussion and guide the direction in which the case unfolds. [F2] shows the introductory page of one such case. When the facilitator believes that relevant issues from a particular page have been explored in sufficient depth and that students have identified areas that require further investigation, the students receive the next page of the case.

During group discussion, students rotate the role of secretary to record the process as prior knowledge is discussed, hypotheses are formulated, and learning issues are identified. As the facilitator probes and challenges the group for understanding, the learning issues that are developed will relate back to the core objectives for the case. [T1] illustrates how this information was recorded during the early group discussion of the first page of the case shown in [F2]. Near the end of the session, students volunteer to research a learning issue of interest to them for presentation at the next group meeting.

It has been our experience that when the students are first learning to identify their own objectives for exploration, an important role of the facilitator is to help the group organize the list of learning issues, sometimes by breaking them down into more manageable parts or by combining simple topics. It is also frequently necessary to help students articulate the specific aspects of the issue they wish to investigate. Using a wide variety of resources of their own choosing, students find texts, original papers, faculty “experts,” material from the Internet, etc, to research their learning issue before the next group meeting. Development of this process of self-directed, independent learning is an important goal of PBL.

<table>
<thead>
<tr>
<th>Identification of data/what do we know?</th>
<th>Additional data wanted/recommendations</th>
<th>Hypotheses</th>
<th>Learning issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 31-year-old man in ER</td>
<td>• What does the smear look like?</td>
<td>Problematic CBC count results:</td>
<td></td>
</tr>
<tr>
<td>• Problem with CBC results:</td>
<td>• Why didn’t the tech re-run the sample before reporting?</td>
<td>• There is something wrong with the sample</td>
<td></td>
</tr>
<tr>
<td>▶ hgb and hct don’t follow “rule of 3”</td>
<td>• Were there previous results to compare to (delta check)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>▶ MCHC and MCH are very high</td>
<td>• Do a manually spun hct to confirm</td>
<td>• clotted</td>
<td></td>
</tr>
<tr>
<td>▶ RBC count is very low</td>
<td>• Try prewarming the specimen</td>
<td>• hemolyzed</td>
<td></td>
</tr>
<tr>
<td>• WBC count is normal</td>
<td>• QA concerns:</td>
<td>Something wrong with the patient:</td>
<td></td>
</tr>
<tr>
<td>• A new hire is running Heme analyzer</td>
<td>▶ Better training needed</td>
<td>▶ cold agglutinins</td>
<td></td>
</tr>
<tr>
<td>• MD is impatient for results</td>
<td>▶ Advice on how to deal with insistant doctors</td>
<td>▶ hemolytic problem</td>
<td></td>
</tr>
<tr>
<td>• Trainer is absent from area</td>
<td></td>
<td>▶ burn patient</td>
<td></td>
</tr>
</tbody>
</table>

This table illustrates the recording of the students’ problem analysis that occurred during the first discussion session involving the first page of the case (see [F2]). As can be seen from the concept map produced at the case conclusion [F1], the hematology problem gradually evolved into a patient problem involving virtually all laboratory disciplines.
MEDT 441/442 Clinical Correlations Session Feedback

Student: ___________________________  Case: ___________________________
Evaluator: ___________________________  Date: ____________  Session#: ____________

<table>
<thead>
<tr>
<th>Needs Improvement</th>
<th>Satisfactory</th>
<th>Excellent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actively contributes ideas/knowledge whether correct or incorrect.</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Supports ideas with prior knowledge / &quot;out-loud&quot; reasoning.</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Asks and answers questions.</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Yields the floor to another person.</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Demonstrates effective listening.</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Respects contributions and/or comments of others.</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Challenges/questions other students on validity of ideas.</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Focuses feedback on the issue, not the person.</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Participates as &quot;secretary&quot; or otherwise helps to organize information/hypotheses.</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Identifies learning issues for self or group.</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Helps to keep group on track—assumes leadership.</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>Is willing to differentiate fact from opinion when questioned.</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

Overall level of critical reasoning achieved in group discussion:

<table>
<thead>
<tr>
<th>Unacceptable:</th>
<th>Literal: identifies main issues, ideas, supporting information, but makes few, if any, connections.</th>
<th>Inferential: identifies cause and effect relationships using data to support reasoning.</th>
<th>Synthesis: draws conclusions, offers new hypotheses, explains how data confirm or refute previous hypotheses, and integrates data/ideas from others in the group.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student fails to contribute to group discussion.</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
</tbody>
</table>

0___________________________5___________________________10__________________________

Oral Presentation of Learning Issues:

Presentation is organized and focused. | [ ] | [ ] |
Information presented is accurate. | [ ] | [ ] |
Utilizes correct technical/scientific vocabulary/terminology. | [ ] | [ ] |
Effectively uses handouts, etc., to enhance group understanding. | [ ] | [ ] |
Clearly demonstrates how learning issue relates to overall problem. | [ ] | [ ] |
Is willing to differentiate fact from opinion when questioned. | [ ] | [ ] |

Overall level of critical reasoning achieved in oral presentation:

<table>
<thead>
<tr>
<th>Literal: identifies main issues, ideas, supporting information, but makes few, if any, connections.</th>
<th>Inferential: identifies cause and effect relationships using data from learning issue to support reasoning.</th>
<th>Synthesis: draws conclusions and/or offers new hypotheses, applying learning issue to the problem, explaining how data confirm or refute previous hypotheses, and integrating data from learning issues of others in the group.</th>
</tr>
</thead>
</table>

0___________________________5___________________________10__________________________

Comments: ___________________________

[F] Session feedback form that provides an ongoing formative evaluation of the student.
MEDT 441/442 Clinical Correlations
End-of-Case Evaluation

Student: ___________________________  Case: ___________________________
Evaluator: ___________________________  Date: ___________________________

Thoroughness of Investigation/Relevancy:
0  Little evidence of investigation of learning issue(s). Unprepared for discussion and presentation. Many obvious aspects of topic unexplored and/or topics researched did not pertain to learning issue.
1  Limited investigation of learning issue. Examines most obvious ideas using predominantly informal resources; little depth of exploration demonstrated. Information obtained may have little relevancy to problem.
2  Examines learning issue in some detail; more subtle ideas may remain unexamined and/or resources are limited in scope or quality. Information obtained is relevant to problem.
3  Examines learning issue thoroughly, showing insight and depth. Resources used show breadth and quality. Information obtained directly relates to and clarifies or explains aspects of the problem.
4  Examines learning issue completely, using and integrating a wide variety of formal, informal, and current resources. Information obtained is used to effectively and efficiently examine, reflect upon, and offer conclusions for various aspects of the problem.

Comments: __________________________________________________________

Supporting Evidence/Deductive Reasoning:
0  Superficial investigation showing numerous generalizations with no supporting sources.
1  Predominantly generalizations presented with a few ideas supported by limited evidence/sources.
2  Few or no generalizations; evidence from more than one source, though limited or superficial in nature, is provided for all ideas. Synthesis or deductive reasoning using information presented in discussion may be limited or may contain fallacies in reasoning.
3  No generalizations; detailed evidence from multiple sources which support all ideas. Satisfactory synthesis or deductive reasoning using information presented in discussion is demonstrated.
4  Clear analysis of the problem with concepts developed and supported by evidence from multiple resources and disciplines. Examination of problem demonstrates sound reasoning, ability to compare and contrast information, and a reflective process leading to appropriate conclusions.

Comments: __________________________________________________________

Accuracy/Understanding of Information:
0  Fails to present information related to the problem and/or own understanding of information presented is not evident.
1  Consistently presents inaccurate information or misinterprets sources. Shows very limited understanding of information presented. May be unwilling to examine accuracy of information when challenged.
2  Some information is inaccurate or misinterpreted. Is willing to reexamine interpretation or information when challenged.
3  Conveys ideas with minimal inaccuracy/misinterpretation and demonstrates good understanding of the topic. Is able to cite at least one credible source when questioned to defend information.
4  Conveys all information accurately and correctly interprets sources, demonstrating excellent understanding of the topic and its relation to the case. Provides multiple resources to substantiate information when challenged.

Comments: __________________________________________________________

[FS] The form filled out at the end of the case by the problem facilitator to provide a descriptive summative evaluation for the student in regard to several key problem-based learning goals.
Order and Clarity of Thoughts:
0   Limited or no organization; discussion disorganized; overall purpose/focus unclear.
1   Although generally organized, group members are left to interpret focus and direction for themselves; meaning of some points is unclear and conclusion is limited or absent.
2   Organization of thoughts clearly indicates what is to follow; discussion may be somewhat disorganized but ideas are generally clear; conclusion is present but may be limited.
3   Thought process is organized. Statements clearly identify what is to follow and meaning of information is clear; conclusion flows logically from discussion.
4   Outstanding organization and focus demonstrated. Major points are clearly delineated and explained, culminating in a rational and insightful conclusion based on the information presented.

Comments: ____________________________________________________________

Contribution to Group Understanding:
0   Little, if any, evidence of contribution of own ideas about problem. Does not contribute to group discussion.
1   Limited contribution of own ideas; may be superficial in reflection. Limited participation in group discussion.
2   Contributes valid ideas but tends to consider aspects of problem separately, rather than as part of a whole. Makes commendable effort to participate in group discussion.
3   Demonstrates thoughtful contribution of own ideas; ideas are integrated into a unified whole and personal biases are recognized and examined. Actively participates in group discussion to aid others in understanding.
4   Consistently reflects upon and contributes own ideas / concepts as well as those presented by others. Synthesizes and communicates information in a manner that clearly enhances group understanding.

Comments: ____________________________________________________________

Teamwork
0   Exhibits unwillingness to function as part of a team. Dominates discussion or doesn’t participate at all; refuses to listen to alternative perspectives; exhibits disrespect for other group members; obstructs or disrupts group process.
1   Collaborative behavior needs work. Participates in group process only with repeated prompting by facilitator or needs to be reminded to yield floor to others; preoccupied or inattentive when others are speaking; unaware of personal biases/emotions affecting own behavior.
2   Developing collaborative skills are exhibited. Is aware of personal biases/emotions and shows corresponding progress to either increase active, constructive participation or decrease dominant or disruptive behavior. Shows respect for others.
3   Demonstrates very good collaborative skills/attitudes. Listens to and considers contributions of others; responds with equanimity when questioned or challenged. Participates constructively in resolving group conflicts. Willing to examine personal biases/emotions.
4   Models exceptional facilitative skills. Works to create accepting environment; actively solicits participation and opinions from all group members. Moves group process forward; actively leads resolution of group conflicts; aids in delegating group responsibilities.

Comments: ____________________________________________________________
**Student Assessment**

One of the challenges in a PBL-based environment is evaluating the students’ learning and development. Assessment may be process-oriented to evaluate skills developed by the student through PBL or outcome-oriented to assess the understanding of content. Our course combines some of each approach. During each discussion session, there are 2 faculty members present, one of whom is the facilitator for the case, the other of whom is responsible for evaluating each student on his or her group interaction and communication skills. The process evaluation tool provided feedback to students regarding their progress on a sliding scale ranging from “needs improvement” to “excellent” [F3]. Measurement is based primarily on the frequency with which a particular behavior or attitude is observed.

For example, a student who never or seldom verbalizes information except when prompted directly by the facilitator would be marked as “needs improvement” on the item “actively contributes ideas/knowledge.” On the other hand, a student who frequently or always speaks up regarding concepts he or she does not understand and who urges the group to examine an issue about which they are clearly all confused would be marked as “excellent” on the item “identifies learning issues for self or group” and on the item “helps to keep group on track.” Because of the subjectivity inherent in these kinds of observations, the same faculty member evaluates the students on process throughout the case in order to provide more consistent feedback. Use of this form enables the students to see where their strengths and weaknesses lie and to track their progress as the case advances.

For assessment of content acquisition, students prepare a written summary of the investigation of their learning issue that explains key concepts and shows specifically how the information helps in understanding aspects of the case including laboratory results, pathophysiologic concepts, and whether it helps to confirm or refute the hypotheses generated. This summary is graded with respect to the effective choice and use of references, depth of investigation and understanding of material, and synthesis of the information as it relates to the case.

At the conclusion of the case, each student has the option of preparing a written summary and synthesis of the entire case, as they understand it, or a concept map that represents their understanding. A concept map may be considered a diagram of the application of scientific concepts linked in a directional manner to explain the data. Concept maps can be useful tools in evaluating the extent of development of the students’ higher order critical thinking and reflective ability. Concept mapping of the case in totality requires the student to organize all of the separate pieces of data and new concepts learned and then synthesize and link them in a meaningful visual interpretation. This process of “mind mapping” helps the student by reinforcing understanding and facilitating internalization of learning for later application.

An example of a student’s concept map of the case described is shown in [F4]. The concept map depicted shows the student’s connections among various laboratory data, concepts, and hypotheses generated throughout the case. It also illustrates the interdisciplinary nature of the case that evolved from the rather simple hematology problem that was presented on the first day. In addition to the concept map or written summary, each student is also evaluated using a descriptive, summative rating form with respect to critical thinking skills, teamwork and interpersonal skills, and presentation and synthesis of the learning issues [F5].

**Our Experience to Date**

Since instituting the PBL-based clinical correlations component in our MT curriculum, faculty have noticed an increased ability of students to evaluate information from multiple perspectives and to integrate content from across the laboratory disciplines to analyze and solve problems in their clinical rotations and didactic course work. From a motivational standpoint, the overall reaction of students to this learning format has been very positive; they are more active learners and show an increased level of ownership of their learning process. Their view of the faculty has gradually shifted from that of a source of test answers toward that of colleagues and a resource in solving problems. Through continued exposure to the PBL environment, the students exhibit a greater ease with communication and presentation skills, including teaching techniques and responding to questions.

One of the unique aspects of our PBL course is the initial participation of faculty as “students.” By having faculty model behaviors that would be expected of PBL group participants, we have noticed that students feel more comfortable with questioning their own and each other’s decisions and conclusions as they observe faculty members doing so. For the faculty, attendance at the cases becomes a form of review and continuing education regarding issues outside their primary area of expertise.

**Conclusion**

The role of the clinical laboratory scientist is evolving. Practitioners are working in multiple areas of the laboratory with less hands-on testing and are increasingly being asked to evaluate laboratory data and apply interpretative analysis before results leave the laboratory. Monitoring of performance parameters, error classification and tracking, and determination of the medical necessity of laboratory testing are playing an increasing role in the MT scope of practice. In addition, managers and educators are encouraging the clinical laboratory professional to play a more active and integrated role in the healthcare team. PBL provides a curricular vehicle through which the students, too, may evolve and grow into professionals with the skills necessary to practice in the clinical laboratory of today as well as advance professionally in the laboratory of tomorrow.