FROM STUDENT LEARNER TO PROFESSIONAL LEARNER: TRAINING FOR LIFELONG LEARNING THROUGH ON-LINE PBL

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Abstract Problem-based learning (PBL) is a constructivist pedagogy in which students learn science and develop critical thinking skills by solving real-world problems in small groups. Studies have shown that PBL students are more motivated and become better learners. However, this pedagogy places additional demands on faculty. It takes time and expertise to develop suitable problems, to coach students, and to facilitate problem-solving sessions. We are developing interactive computer systems incorporating the PBL approach which (1) help teachers design, enter, and share problems, and (2) support students and guide them through the PBL inquiry process and (3) assist teachers to continue their professional development by improving their domain knowledge. System development is guided by K-16 educators and tested in classrooms. Our goal is to enable educators to adopt this pedagogy in K-16 classrooms with minimal overhead and to assist them to effortlessly learn new technologies and new material.

PBL AND ITS BENEFITS

Problem-based learning (PBL) is a constructivist educational approach that organizes curriculum and instruction around carefully crafted “ill-structured” problems (Barrows, 1988). Guided by teachers acting as cognitive coaches, students develop critical thinking, problem solving, and collaborative skills as they identify problems, formulate hypotheses, conduct data searches, perform experiments, formulate solutions and determine the best “fit” of solutions to the conditions of the problem. Problem-based learning enables students to embrace complexity, find relevance and joy in their learning, and enhance their capacity for creative and responsible real-world problem solving.

Students often ascribe their lack of interest to the poor real-world relevance of their courses. Studies by educational psychologists and cognitive scientists indicate that problem- and project-based learning centered around authentic problems are more likely to motivate students to think deeply about the domain being learned (Ram & Leake, 1995). In PBL, students are required to take on the responsibility of learning. Such students tend to be more motivated and to become better learners (Bereiter & Scardamalia, 1989). Involvement with the subject matter, as when students work on a challenging task, leads to an increased retention of students in science.

In today’s fast-paced technology-driven world, students not only need to learn the subject matter but they need to develop the skills of lifelong learning as well. As knowledge changes, students need to develop strategies for self-assessing their knowledge and planning their learning when a teacher is not there to direct them. Being a self-directed learner requires that individuals identify their knowledge deficiencies relative to a task being undertaken, generate a plan to remedy those deficiencies using appropriate resources, carry out the plan, and evaluate the results in the context of the problem to be solved (Ram & Leake, 1995). PBL provides opportunities for self-directed learning and self-assessment.

In addition, when students mature into teachers, quite often the courses they teach do not overlap with their original areas of expertise. A teacher could be assigned to teach a course that is unfamiliar to them or where advances in the field have overtaken their original expertise. Changing curricular expectations, new school standards and new requirements are constantly being placed on teachers as the educational system is being deemed unsatisfactory. This is especially critical in math and science. The lack of domain expertise is a critical problem facing the education system today and school systems are looking for effective and economical ways to retrain teachers both in pedagogy and content.

Finally, students need to learn problem solving and scientific reasoning skills in addition to conceptual knowledge. Problem solving is best learned when it is integrated with learning in a domain (Brown, Collins, & Duguid, 1989; Ram, 1999). Teachers need pedagogies that can teach their students problem solving skills. PBL specifically engages students in solving large complex, interdisciplinary problems while emphasizing the need for a deep, conceptual understanding.

From its origins in medical instruction, PBL has been adapted to both K-12 education and undergraduate education (see K-12 URLs). Practitioners of PBL have adapted the pedagogy for younger audiences, taking into account the greater structure of school curricula and the need to address standards. Much of the current research in PBL has been primarily with adult learners who have previously demonstrated high levels of academic proficiency and with gifted students. In fact, some educators of gifted students have enthusiastically embraced PBL, because it possesses attributes that are viewed as parallel to common characteristics of gifted children. Recently, Gordon et al (2001) studied the effect of PBL on low-income and minority school aged populations with very positive findings. When used as an enrichment activity for 2% of the curriculum, they observed a significant improvement in the behavior and increased science performance of low-income minority middle school students.

CHALLENGES IN ADOPTING PBL

Despite the many benefits of PBL pedagogies, PBL is still not widely used in K-16 classrooms. One serious challenge faced by even expert practitioners of PBL is the intense demands this pedagogy places on faculty. It takes time to develop good problems and more time to facilitate the sessions. Designing a problem involves choosing an authentic real-world problem that the students can relate to. A problem has to require some final product(s). A good problem has to be designed to support multiple hypotheses, present itself without too much “given” information, be open-ended, and “messy”. In addition, students work on problems in small groups, requiring faculty to devote significant amounts of time guiding students through the PBL process. In larger classes, student-faculty ratios do not permit this level of individualized guidance.

HOW CAN TECHNOLOGY HELP?

Educational technology holds the promise of diminishing the burden on the instructor by streamlining the problem design and instructional processes. In today’s classroom, computers are being increasingly used to provide many kinds of resources: online books and manuals, online homework assignments with grading and feedback. Web-based learning environments are advantageous in that they can offer personalized learning tools to students of different abilities in and out of the classroom. However, typical web-based tutoring systems are not often designed to be challenging, interesting and deliver curricular material with a sound instructional pedagogy. We argue that web-based learning environments based on PBL can offer the advantages of both the technology and the pedagogy and overcome the drawbacks mentioned above.

Our first web PBL environment, Virtual Sherlock was a successful implementation in a sophomore undergraduate analytical chemistry lab (Ram et al, 2000). Our latest environment, CaseBook, expands the scope to enable PBL to be used by different educators in different classrooms. CaseBook makes it easy for educators to develop their own web-based PBL units, share them with other educators, and use them in their classrooms. PBL units, called "cases", reside in a searchable database and can be selected for use in the classroom. A user-friendly student interface allows students to work collaboratively on the selected cases, with the system guiding them through the stages of the PBL process.

We have been working with school teachers and science coordinators in four school systems, Atlanta Public Schools, Decatur City Schools, Fulton County Schools, and Dekalb County Schools. Teachers trained in PBL have developed and implemented several cases. (Information about this project is available at www.sciencenet.emory.edu/prism.) The system was also tested in Fall 2004 with first year chemistry students in a general chemistry class. The system will also be tested in Spring of 2005 in a first year biology lab. Both college courses are being offered at Emory University. Teachers at two different school sites will be testing the system in Spring 2005. The database now includes cases for the sciences and for students at both college and pre-college level. This database of teacher-tested and school system-approved cases can be used by teachers and students via a simple web-based interface.

THE CASEBOOK SYSTEM

CaseBook is designed with four complementary components. CaseManager allows teachers to choose the right cases for their class, add student information, create groups, and monitor student progress. CaseExplorer provides a problem-solving environment that guides students through the PBL process. CaseMaker teachers to enter and modify cases, guiding them through the case creation process via a web-based palette. Finally, an internal component called CaseLibrary serves as a central repository or database of cases. Let us discuss CaseExplorer first as it is the core of the PBL process.

CaseExplorer

CaseExplorer guides students through the PBL inquiry process (see figure 1). Cases are divided into scenes. Students work collaboratively on each scene in a three-stage process: Analyze, Learn, and Reflect. In the Analyze stage, students elicit data about the problem (Facts), generate ideas and hypotheses (Ideas), and identify questions and gaps in their knowledge (Questions). The Viewer shows the problem statement (Scenario). Group members share a Team Notebook, in which they record their Facts, Ideas and Issues via an online NotePad. At the end of the stage, they CheckIn their Notebook which automatically publishes their information for the teacher to view and provide feedback.

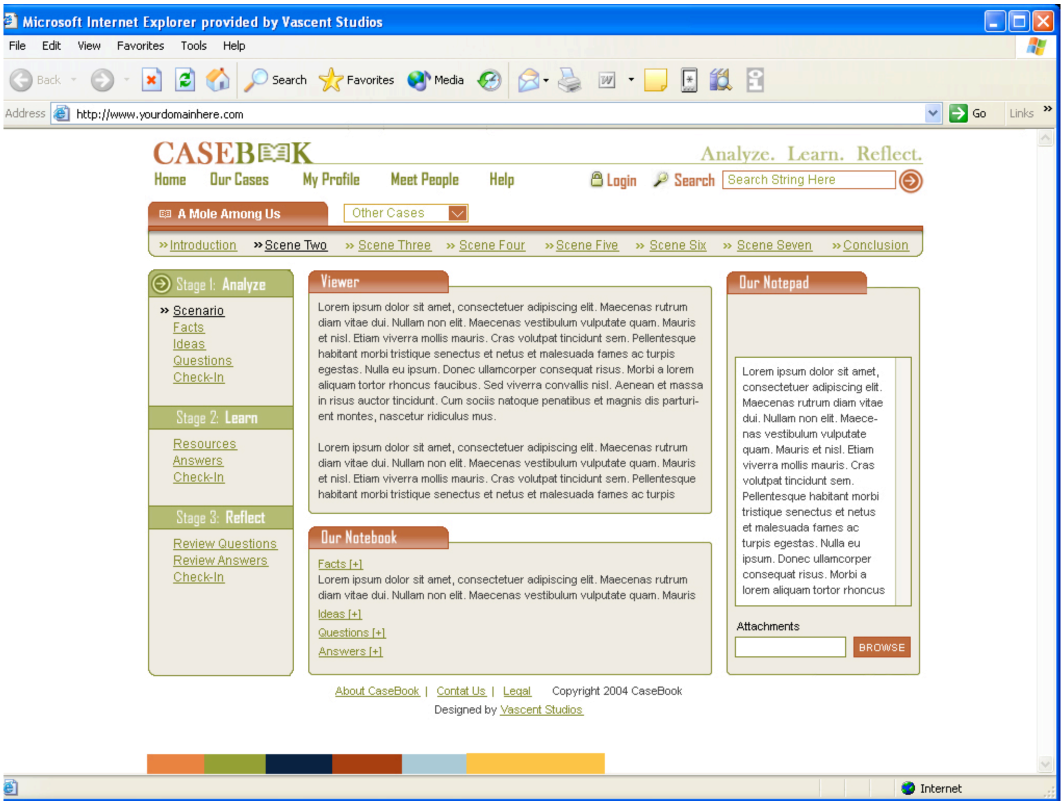

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Figure 1: View of CaseExplorer

In the Learn Stage, students seek to answer their Questions via self-directed learning. They start their self-study by exploring teacher-provided Resources or access online textbooks or journals. These Resources can be tailored to the level of the class. For a college level class, one does not even have to have any suggested resources. Students work in groups to research their Learning Issues and meet to discuss their results, just as in a face-to-face PBL session. These group sessions are a critical element of the PBL process. Students learn to explore the topic and learn to search for information independently. The availability of the case on line allows for asynchronous learning without diminishing the peer group interactions and group learning. Once the group has negotiated a set of answers to post, the results of their self-study (Answers) are recorded in the Notebook using the NotePad and published via CheckIn for the teacher's feedback.

The final stage, crucial to true, sustainable learning, is called Reflect. Students together, answer Review Questions that probe their depth of understanding, and their Review Answers provide a quick rubric to assessing their progress. Again, it is to be emphasized that if a group setting, the students have to collectively agree on an answer through discussion before they post the replies. After this stage, the group moves on to the next scene in the case.

As students work through the scenes, they are always able to review their Notebook and view the Notebooks of other groups at the same level as themselves. Teachers can annotate the student Notebooks and provide feedback at any time. Students in a given group are encouraged to collaborate and discuss through an online chat room (Meet People) with other groups. At the end of the case, students perform a Self-Evaluation which is also recorded in their Notebook for teacher feedback.

CaseMaker

A major benefit of the CaseBook architecture is the ease of development of new cases via a use-friendly web-based environment. Educators can create their own media-rich PBL units without needing a programmer or programming skills. Educators can share their problems, allowing other classes and educators to use the problems they've created and contributing to a growing database of problems. Moreover, just as the CaseExplorer leads students through the inquiry process and ultimately helps them learn the process, CaseMaker provides guidance on problem development and access to case analyses and case notes from other teachers to guide the choice of a case and its implementation in class. Teachers are immediately connected to a network of like-minded teachers in an online community.

CaseMaker provides several tools for creating cases. Cases can be divided into one or more scenes. This allows for flexibility in use, accommodating one-hour sessions, laboratory exercises, and multi-week projects. An easy-to-use Scenario Editor allows cases to be edited in a Microsoft Word-like manner without HTML knowledge. Documents, images, graphs, and URLs can be included to provide students with additional resources when they explore the problem. Educators may copy an existing case from the CaseLibrary and modify it to suit their own objectives.

CaseManager

CaseManager includes administrative functions such as importing class rolls, organizing students into groups, and searching and selecting cases for a course from the CaseLibrary. It also lets the teacher monitor student Notebooks and discussions in the online chat room, and provides feedback via an online NotePad.

CaseLibrary

Completed cases on every topic are stored in the CaseLibrary, and are made available for use and modification by any instructor in any class. Modified cases are made available as a subsequent version, retaining the original version under the original author's name. Cases contain not only the scenes for students to work on but also the learning objectives and curriculum goals as well as suggestions for implementation, feedback from other instructors rating how well the case fit into their particular course, and statistics tracking how often a case has been used in a course. Cases often integrate learning objectives from different topics, helping students understand the material in a broader context rather then treating each topic in isolation.

A SAMPLE CASE

Amy's Ailment (Created by Nicole King)

Level: AP chemistry and freshmen chemistry

Main Objectives

To understand chemical kinetics, to construct a relate law equation, to understand the role of catalysts and how they work in the rate law, to perform internet research (esp. on a medical topic).

Secondary Objectives

Review of: Writing/balancing a reaction, concentration units, stoichiometry, redox chemistry.

Scene 1

"First snow of the season!" Steven shouts as she looks out of the window to see snowflakes hitting the ground and building on the sidewalk.

"Snow!?!" Amy shouts excitedly. She is from St. Thomas, and has lived there all of her life. She is visiting her boyfriend in Ohio. She has never seen snow before. "Oh let's go play in it!" Amy exclaims, dashing for the door.

"Hold up," Steven laughs. "We have to dress a bit warmer first. I don't think a t-shirt and jeans is going to cut it."

The couple laughs and jokes as they put on their sweaters, coats, and other winter accessories. Amy is eager to do all of the things in the snow that she's about; making snow angels, snowmen, snowball fights. By lunch time she's tried them all.

Three days later, and Amy and Steven are back at Emory preparing to finish up the semester. After a long day of classes and lab, Amy sleeps soundly but wakes a couple of hours later to violent chills. She is dripping in sweat and has a fever of 105. She calls Steven who rushes her to the hospital on campus.

By the time they get there, her breathing rate has increased and her lips start to turn blue. The doctors want to run a few tests, but it will take a while for the results. Meanwhile they want to do something to help Amy's breathing. A young doctor suggests intravenous hydrogen peroxide solution.

"Isn't that poisonous?" Steven asks.

"The decomposition of hydrogen peroxide will help with her breathing. And if she has an infection, which it is very likely that she does, it will help that too," the doctor retorts.

Steven is still suspicious of all this fancy young doctor talk, as he looks over at Amy struggling for breath. "Alright…." He reluctantly agrees.

Stage 1: Analyze

Facts	**Ideas**	**Questions**
Amy was out in the snow before she got sick. Amy traveled from Ohio to Atlanta (climate change). The doctor says H_2O_2 will help with breathing and infection.	She may have caught pneumonia in the snow. She has caught an infection from Steve.	How can one tell if she has an infection? How can one is she has pneumonia? What is hydrogen peroxide? What is its formula? What are its chemical properties? Why does the doctor say it will help with her breathing? Is hydrogen peroxide harmful to the body? What is the reaction for the decomposition of hydrogen peroxide? How will this

		reaction help Amy's condition?

(These are some actual examples generated by students.)

Stage 2: Learn

Resources	**Answers**
Web Resources www.medical-library.net www.mednets.com science.uniserve.edu www.sefsc.noaa.gov/HTMLdocs/HydrogenPeroxide10.htm www.sefsc.noaa.gov/HTMLdocs/HydrogenPeroxide3.htm www.utmb.edu yarchive.net/explosives/peroxide.html www.discoverycentermuseum.org/experiments/213.htm ***Textbook*** Chapter 13, Chemistry: An Integrated Approach, Hill and Petrucci, 3rd Edition	[Answers to the questions generated above]

Stage 3: Reflect

Review Questions	**Review Answers** *These depend on the level of student research. Some student-generated examples are quoted here.*
Does Steven have a valid concern?	H_2O_2 can be dangerous at high concentration (like most things). It can be harmful if taken orally, but not deadly. Also, H_2O_2 has the potential to decompose into hydroxyl radicals. Radicals, although sometimes present in the body naturally, can attack many things in the body.
Write out the decomposition reaction of hydrogen peroxide. How might this help with Amy's breathing?	$H_2O_2 \rightarrow H_2O + 1/2\ O_2$ or $2H_2O_2 \rightarrow 2H_2O + O_2$ The presence of oxygen, which is lacking if she is hyperventilating. Also the potential for O_2 as an oxidizing agent in many of the body's processes.
Use thermochemical data to find out if this reaction is spontaneous.	The enthalpy of reaction DH is -26.04 kcal/mol. DS for the reaction is probably positive because it is becoming more random. DG is negative, if DH is – and DS is + so it would be spontaneous.
Why does the doctor also think this may help if she has an infection?	The oxidative properties of O_2 might kill bacteria.

EVALUATION AND PRELIMINARY RESULTS

50 students were enrolled in the fall semester of a general chemistry course. Students were given some information about PBL prior to registering, but apparently it was not sufficiently detailed.

Students were asked to work on three cases in groups of three to five outside class hours. Group assignments for the first case were made by random assignment but for cases two and three, were made based on student preference. About half the week's class time was spent on introducing casebook and the case to students. Advanced students who were familiar with the course and with PBL were assigned to be available during weekends to help. Students needed about two to three weeks to complete a case. During this time, at least one class was spent on discussing students' progress on the case. In addition, students were able to post their reactions and problems on an online bulletin board monitored by the faculty and the student helpers.

The cases all covered not only material that was being covered in class, but also material that students had not yet encountered. By the time we had progressed to the third case, it covered material that had been covered earlier in the semester. They were integrated cases and required students to acquire information from chemistry as well as other fields.

Initial response to the first case was quite negative. Students needed a lot of help getting used the interface. We are working on these aspects of the system. Students questioned the relevance of the material they encountered in the case to the course. Students also needed to be encouraged to learn information on their own. They are too used to being told exactly what to learn, they found it very unsettling to have to decide what to look up. Faculty can provide feedback and guidance through the annotation function available in CaseBook and this proved to be really helpful.

By the second case most students were better able to handle the case. The new self-selected groups helped reduce logistical issues of meeting times and schedules. The second case had some issue dealing with heroin abuse and physiology and our students really enjoyed that. By the third case, the quality of the postings had improved and the number of complaints had dropped significantly. Several students commented very favorably on PBL and were asking for a follow up semester with PBL.

Evaluation of PBL is always difficult. Regular testing protocols for large introductory courses are usually composed of multiple-choice questions. The skills learned in a PBL setting involve collaborative learning, looking for information from multiple sources, which are usually not allowed in most college classroom exams, and forming hypotheses and solving complex multi-step problems. We decided to focus on testing a subset of skills acquired through the PBL experience.

We adopted two different strategies to evaluate the effect of PBL on this population. We had questions in the exam that were directly related to content they ought to have mastered through working on the course. We also had a longer and more complex problem than is usually found in general chemistry exams. The problem was multi step and had a fair amount of irrelevant information. Students were required to go through the PBL process, identify the Facts, the Ideas and the Learning Issues and then work on the problem. In our opinion this was definitely a radical departure from the standard multiple-choice questions encountered by students in these courses. In addition to collecting this information, we also handed out a survey and collected their comments at the end of the course.

We noticed that the average of the questions that dealt with direct content knowledge (82%) was the same as the class test average (81%). The average of the complex multi-step PBL problem was a little lower than the class average 76%, contrasted with 81%. The overall average for the PBL problems was 77%. As we can see students fared a little more poorly on the more challenging PBL problems but the correlation between the PBL grade and the overall test grade was quite good (correlation of 0.66). We are continuing to collect additional data this semester. We will be looking at how these fifty students perform in a follow up semester of general chemistry. Typically students perform poorly in the second semester compared to the first semester. We will determine if our students trained in PBL techniques will do any better than the general pool.

This semester we are using CaseBook in two different settings: an undergraduate Biology lab course and a high school chemistry/biology course. Feedback collected from these two settings will inform future design of CaseBook.

CONCLUSION

This paper describes a software system that seamlessly integrates case development, classroom implementation, archival of student interactions, and a database of cases and case notes. The system allows educators to introduce PBL in their classrooms with minimal effort. The system trains students to use the PBL process, while maintaining the key principles of PBL, at a much lower involvement of faculty time. While the system software cannot yet duplicate all the functions of a PBL facililtator, it is a first attempt in that direction and can deliver a problem solving and collaborative experience that is certainly more engaging than a standard lecture. It is this baseline that we are comparing CaseBook against, not the ideal situation of small facilitated groups. Increased implementation of hands-on, inquiry-based, context-driven and collaborative pedagogies will make a significant difference to the educational experience of the student and the skills they acquire. Technology offers the opportunity to increase adoption of problem-based learning in K-16 classrooms.

Teachers can also use CaseBook and work through the cases individually to learn new material. The system can therefore serve as an excellent professional development tool. Since teachers tend to teach as they were taught, as they develop familiarity with new material, learning through a PBL environment, we expect more teachers to be able to adopt this pedagogy in their classrooms. Technology will offer them the opportunity for individualized private self-instruction, but with a richer learning experience than a traditional e-learning course.

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K-12 URLS

1. Center for Problem-Based Learning. http://www.imsa.edu/team/cpbl/center.html
2. Bug Bitten. http://www.edcoe.k12.ca.us/bugmain.html
3. Alien Rescue. http://stardate.utexas.edu/marykay/rescue.html
4. U Buy A Car. http://www.mcli.dist.maricopa.edu/pbl/ubuystudent/index.html
5. NASA. http://whyfiles.larc.nasa.gov/text/educators/activities/2000_2001/pbl/pbl_flight.html