Multi-Electronic Media Classroom for Computer–Aided
Problem-Based Learning

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Abstract

A new paradigm is rapidly developing, with the increasing electronic sophistication of teaching methods and classrooms, for problem-based learning (PBL). This paper describes the study being performed in the Chemical Engineering Department at Lamar University to integrate best practice pedagogy with computer-aided modeling and simulation into a PBL educational program. The program requires a multi-electronic media classroom for computer–aided problem-based learning. A prototype modern classroom will be discussed in terms of the pedagogical objectives of PBL. From experience with the prototype classroom, a new classroom has been designed to optimize the PBL learning process.

Introduction

This paper is the result of an adaptation and implementation proposal that is funded under the Course, Curriculum and Laboratory Improvement Program of the National Science Foundation1. It involves the innovative use and extension of problem-based learning (PBL) in Chemical Engineering education at Lamar University. The project focuses on the integration of computer-aided modeling and simulation into the courses and curriculum of both undergraduate and graduate education. It seeks to answer the questions: a) what are the best strategies for integrating modeling and simulation into the curriculum, courses, and the laboratory, b) how can computer related tools promote integrative strategies for research and learning in the context of PBL, c) what are the best modeling and simulation tools and techniques available for teaching chemical engineering and providing the student with the understanding, appreciation, and skills to use the techniques properly for specific problems, d) what are the best ways to evaluate the success of the teaching strategies, and e) what classroom architecture and innovations are needed to support this integration. This paper addresses the last of these questions.
Problem Based Learning

Problem based learning (PBL) is broadly defined as an educational approach to structuring curriculum and courses that involves facing students with problems that provide a stimulus to learning. It has the following attributes:

- Learning is student centered.
- Learning occurs in small student groups.
- Teachers are facilitators or guides.
- Problems form the organizing focus and stimulus for learning.
- Problems are a vehicle for the development of clinical problem-solving skills.
- New information is acquired through self-directed learning.

PBL is undergoing a renaissance in engineering education and precedents exist for the incorporation of computer-aided modeling and simulation into the process. Smith, at the University of Minnesota has incorporated computer based modeling technology into a problem-based freshmen course. Problem based learning parallels the general order of the scientific method: 1) identification of the problem, 2) definition of the problem, 3) formulation of hypotheses, 4) projection of consequences and 5) testing the hypotheses. The process of problem-based learning is:

- Students confront a problem that they have helped to identify
- Students, working in well defined groups, organize prior knowledge and attempt to identify the nature of the problem
- Students pose questions about what they need to delineate to gain understanding
- Students formulate a strategy to solve the problem and identify the methodology and resources they need.
- Students continue to gather and process information as they work to solve the problem.

According to Savoie and Hughes, a problem-based learning experience should involve the following actions by the instructor:

1. Help in identifying a problem suitable for the students.
2. Help connect the problem with the context of the students' world so that it presents authentic opportunities.
3. Help organize the subject matter around the problem, not the discipline.
4. Give students responsibility for defining their learning experience and planning to solve the problem.
5. Encourage collaboration by creating learning teams and working with them.
6. Expect all students to demonstrate the results of their learning through a product or performance.

**Simulation and Modeling**

In this project, commercial modeling software packages such as (but not limited to) Breeze, Epcon, HYSYS, AspenPlus, ProII, DMCPlus\textsuperscript{10} and MathCad are being used. The software packages are not being used as “black boxes” or mere tools from which to extract solutions, but are being used to enhance the fundamental understanding of the principles on which modeling and simulation tools are based. Also, considerable effort is being made to make use of university-developed modules such as the Purdue Computer Simulation Modules, the Michigan Modules, Chemical Reactor Design Tools, and other software packages. In addition, visualization\textsuperscript{11}, virtual reality and hypermedia tools are being accessed as needed\textsuperscript{12}. A new visualization and editing software made by Sectorware\textsuperscript{9} will be highlighted. Associated with it and the classroom are a Sony digital camera (Sony DSC-F707 Cyber–Shot) and a digital video camera, which are being used by the PBL, groups to obtain original images and videos for problem solutions and reporting.

**Classroom Innovations**

University classroom design has been traditionally conservative with the legacy of the traditional science-based classroom as its base\textsuperscript{13}. However, problem based learning has demanded more flexible classroom designs. These include 1) a level floor, movable seats and tables, no central seminar table, easy access to wall mounted writing board and a design that still allows instructor-focused lecturing. Adding electronic-based multi-media and computer-aided learning methods has raised additional demands on the classroom architectural design. Traditional arrangements of computer laboratories and classrooms having the computers on tabletops in long rows totally defeats problem based learning.

**CCLI Prototype Classroom**

**Group Operation:** After PBL groups form, there is a need for the instructor to meet periodically with each group, for mentoring and tutoring. These meetings can be face-to-face, by conference call, by chat room or web meeting. The dominance of information collection and processing in the PBL process is ideal for the use of electronic resources for collection, compilation and utilization of this information. In the PBL process being used in Chemical Engineering, the information generated by a particular group is generally stored and made available to the class in the form of Power Point Presentations. These are placed on the Class’s web page site and can be accessed by the entire class. Students also maintain individual folders.
on the web site, which allow monitoring of each students contribution to the information manipulation and aids in assessment.

Also, it is quite common to have the groups functioning in the classroom. This is where proper classroom design in paramount.

**Classroom Architecture**

This project has been using a small prototype computer based classroom\textsuperscript{14} to test the principals of PBL and computer-aided learning. It is schematically shown in Figure 1. It is designed to accommodate up to four PBL groups, with each having an electronic white board for the recording discussions. The classroom has the following layout and equipment: It is served by a CISCO Aironet 350 Wireless Networking System. The main server for the instructor is a Gateway E-4600 SE with Windows 2000 Server. The students have six Client Computers - Gateway E-1600 SE with Windows 2000 Professional. There are four electronic 4’x 6’white boards. In addition, there is a Toshiba TPL 671 LCD Projector and a Webcam in the classroom.

**Electronic White Board**

The electronic white boards allow the instructor and PBL groups to:

- Save everything written or drawn on the board instantaneously to PC
- Record what all that is written in 4 colors.
- Send e-mails, or posts notes directly to the department web site to share with colleagues world-wide
- Support real time teleconferencing with remote participants
- Use Projection Screen Support to makes white boards as touch-sensitive projection screens by connecting to them to PC’s and the LCD Projector.

**Multimedia Electronic Projector with Overhead Camera**

This projector shown in Figure 2, is an important unit in the classroom since it allows transparencies and textbook materials to be projected. The focusing and zoom camera allows the easy transition for instructors who

Figure 2 Toshiba TPL 671 LCD Projector
have materials on transparencies and/or are still depending on textbook use in the classroom. This has been essential to getting faculty to actively participate in the PBL project.

WebCam

WebCam technology has opened a level of instructor–student, student-student and instructor-PBL group interaction never before anticipated. Distance separating the educational participants, images, information and ideas has now diminished to the point that these can be shared to become a support of common, and simultaneous work. The mentor-instructor in PBL now can work on joint projects with students from any location. This allows students in diffuse locations to be active participants in PBL group activities. In particular, the WebCam is used for videoconferences with individual groups allowing the instructor to participate in one or more PBL groups from remote locations. It also allows material to be digitized and transmitted to the class by e-mail or other digital recording media.

Virtual Reality

The use of virtual reality (VR) in chemical engineering education as pioneered by Fogler and associates\textsuperscript{15} will be added to the classroom in the near future. The classroom is equipped with virtual reality headsets (Cy-visor head-mounted computer display) that are being used to perfect the integration of VR into the PBL program.

Paperless Design

Hypermedia in the classroom has, to a large extent, removed the burden of student’s manual note taking, since virtually all materials can be electronically based or electronically captured and e-mailed to the students. This frees the students to concentrate on the information being discussed in class and aids considerably in promoting the PBL working groups’ activities. It allows students to become more involved in class discussions and in interacting with the instructor. The availability of the electronic white boards for each PBL group allows the capture of written documentation of discussions and allows the instructor to review all materials discussed by each group. The era of the paperless classroom is today a reality.

Learning Examples (Initiation of PBL)

We have presented parts of our project in two engineering education conferences\textsuperscript{16,17}. This new CCLI Prototype Classroom equipped with Electronic White Boards has been examined for the first time in a chemical engineering undergraduate class, Advanced Analysis. The Advanced Analysis is a senior course, which traditionally is based on mathematical methods in chemical
engineering. With powerful modern computer packages, this course is now placing emphasis on modeling of systems, solving system equations, and interpretation of the results.

To fully use PBL pedagogy, students begin searching for a problem, formulate a description of the problem and then seek its solution. However in the early stages of PBL, in a given class, the instructor can choose to provide a description of the problem a week or so before class discussions begin and thereby give students time to understand the problem, search for relevant references and prepare for class discussions. Here, an exemplary, simple problem selected from Jenson and Jeffreys will be used to illustrate the process of initiating PBL in a class such as Advanced Analysis. “The problem is:

A tank contains 2 m$^3$ of water. A stream of brine containing 20 kg/m$^3$ of salt is fed into the tank at a rate of 0.02 m$^3$/s. Liquid flows from the tank at a rate of 0.01 m$^3$/s. What is the salt concentration in the tank when the tank contains 4 m$^3$ of brine? Plot the salt concentration and the volume versus time.

Students are encouraged to participate in the modeling of the system. The modeling process usually starts with the first principles, i.e. material and energy balance. To make modeling possible, assumptions are required. Typical assumptions for discussion are:

1. Will the liquid volume be changed after mixing?
2. Will the temperature be the same after mixing?
3. Will the brine concentration in the outlet be the same as that in the tank?

Because of the electronic boards, the students do not have to worry about manually taking notes. Instead, they can concentrate on the discussions of the modeling process. The instructor gives only guidance not the “solution”. All pertinent facets of each assumption should be explored and discussed. A reasonable assumption can be recognized, but not assigned. Because of all students participate; they gain a better understanding of the problem than with the traditional one-way lecture and problem assignments.

To solve the system equations, the class is split into two groups. One group uses computer packages such as PolyMath while the other uses analytical methods. Both numerical and analytical solutions are presented and compared. A question about truncation errors and round-off errors is usually initiated in the discussion and the instructor is prepared to give guidance and even answer questions if the students are not familiar with the Runge-Kutta numerical method.

The students present their results through a computer network with the LCD projector after optimizing the presentation in group discussions. The interpretations are open to the discussion. For this example, the solutions are straightforward: the brine concentration increases.
exponentially while the volume increases linearly with time. For other more complicated systems, the discussions of the results are can get very involved. Through these discussions the students achieve a much deeper and broad understanding of the problems. Most of the students also find that it is very helpful to understand the system behavior through the discussions of the results. This part, the interpretation of the results concludes the PBL process.

Another part of the Advanced Analysis course is the safety case study. The class is separated into three groups for study of the following three cases:

1. Piper Alpha – Spiral to Disaster
2. Phillips 66 Company Explosion and Fire at Pasadena, Texas
3. Methacrylic Acid, Tankcar Explosion and Methods of Safety Handling

All these three cases are from the Safety and Chemical Engineering Education (SACH) Division in the American Institute of Chemical Engineers (AIChE).

The material, including video and CD are distributed to the group one week before the group presentations. The students watch the videos/CD’s, discuss the events that occurred, and then analyzed the safety considerations. The students use the electronic boards for group discussions. The instructor monitors the group discussion from the instructor’s station but does not interrupt their discussions. All the group’s discussion materials are saved into the computer without note taking or typing. Students reach much more involved levels in their discussions in this environment than previously noted under normal classroom environments.

We find this type of “problem-based” and “student-centered” discussion and learning is very effective in initiating students into the PBL process. Every student is challenged to participate and contribute to the problem solving. These are critical first skills for PBL.

A New PBL Computer Based Classroom

The use of the prototype electronic classroom described above has resulted in the design of a new classroom (Figure 3) that will be incorporated in our program for engineering education. It goes beyond the “conventional” electronic classroom and adds a dimension of separation of groups, yet maintains the unity of an instructor-controlled classroom. It requires that the instructor be located in the center of the classroom with a podium containing a master server, web camera, and digital projector with camera. Located above the podium will be four plasma computer screens that are connected to the master server and can be controlled as a unit or separately to provide visual information to each group. Each PBL group will have six computers and an electronic whiteboard. These will be used in group discussions. The master server will
monitor all white boards and all computers. This will allow instructor participation in the group activities.

Conclusions

A change from instructor-centered to student-centered, computer-aided PBL learning in higher education poses challenges for administrators, educators, students and classroom designers. Computer-based PBL classrooms must be carefully designed to meet the pedagogical objectives. In the case of computer-aided PBL, the modern electronic classroom is essential for optimization of the PBL process and requires special design\textsuperscript{20,21,22}.

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References

1. National Science Foundation: #9981152 titled “Integrating Best Practice Pedagogy with Computer-Aided Modeling and Simulation to Improve Undergraduate Chemical Engineering Education”.


15. Fogler, H. Scott, NSF Division of Undergraduate Education - Award ID: 9555094 “Low-Cost Virtual Reality as an Educational Tool: Application to Undergraduate Chemical Engineering and Development of Pedagogical Implementation Techniques”.


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