Problem Based Learning: Applications for College Mathematics and Allied Health

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Introduction

Problem based learning (PBL) is a non-traditional teaching method that encourages collaboration and higher-level critical thinking skills on part of the learner and the instructor. The following discussion focuses on the mathematical needs of all developmental mathematics students, in particular those students who are pursuing a path in allied health and who require basic mathematics skills to function as a practicing professional. In contrast to the traditional instructional paradigm, whereby teachers lecture and students listen, PBL offers a better method that incorporates class discussion groups, and promotes independent and team learning skills.

The Problem

Dale Parnell, former president of the Association of Community Colleges, estimated that "more than 23 million individuals in the United States cannot read, write or compute at the functional level and many of the students turn to the community college for help." And, in fact, between 60 and 75 percent of entering community college freshmen need remediation in mathematics in order to succeed in a college environment. (Cox, 1993) Unfortunately, the failure rate in such courses is alarming and unacceptable. According to one study of students enrolled in developmental mathematics courses, fewer than half are able to pass the course on their first attempt. (Hackett, 1985).

Many students have the aptitude necessary to successfully complete the health curriculum of their choice and make fine practitioners. However, these health careers require substantial training with a strong mathematics and science background, and many programs are finding it increasingly
difficult to attract people because of their fear of mathematics. For example, students in the imaging and radiation therapy professions are required to have a strong understanding of mathematics in order to apply ionizing radiation to patients and to administer contrast media and radiopharmaceuticals. Mathematics skills are also vital in radiation protection calculations, such as the inverse square law, density histograms and radiation dose response curves.

To prepare students, instructors from applied fields need to work with mathematics instructors to develop an approach that provides a common goal by addressing the students’ needs with an appreciation for the employers’ demands. This approach, called problem-based learning (PBL), is an instructional method that incorporates class discussion groups, and promotes independent and team learning skills.

With jobs in the allied health professions expected to steadily increase over the next five years, there will be an increased demand for highly trained professionals who are proficient in mathematics calculations. To master this-level of mathematics, some students may need developmental or remedial courses. An increased emphasis on directly relating developmental mathematics to health applications will give students the opportunity to use material and concepts learned and relate this information to their career. Although we use allied health as the “example” from our own personal PBL teaching experiences, this method can be used in all developmental mathematics, and higher-level mathematics, to promote an improved level of critical thinking and problem solving skills that will more directly address employers concerns.

The Proposed Method

Learning (not teaching) is the PBL emphasis. The current view in many higher education programs is that we should focus on student learning, rather than on the traditional formal teaching environment, to improve students’ skills. The shift from teaching to learning has been endorsed by many prominent leaders and theorists in higher education, including Huba and Freed, since the mid-1980s. (Huba and Freed, 2000)

Many teachers feel that presenting mathematics via problem-based learning is a better way to promote a higher level of problem solving skills. As educators, we so often prevent the “messiness” in problem solving by our means of instruction. PBL allows for messiness, which reflects the real world in which we live in. We tend to systematically deliver material to our students and expect them to repeat it as if they were transcribing and not learning. Problem based learning focuses on the learning that takes place as
a result of the process of working towards and resolving a problem. It involves self-acquisition of knowledge, directed learning strategies, and teamwork and problem solving tasks, all of which reflect the "real world" dynamics involved in solving problems.

As compared to the traditional teaching paradigm that we are all very familiar with as instructors and learners, PBL offers a new environment to stimulate learning. Typical instructional delivery is primarily textbook driven, focuses on learning factual information and isolated skills, and teaches a sequence of skills and concepts that is teacher defined. In contrast, PBL promotes engagement, inquiry, investigation and performance, all of which require a higher level of thinking and promotes a better level of long-term retention of material.

**A Problem Based Learning Example in Radiology**

When you get an x-ray you might wonder, how the radiographer determines the distance the source of the x-ray needs to be from the film (in radiology this is referred to as source to image receptor distance (SID))? The distance the x-ray source is from the film affects the density of the film (density refers to the amount of darkness on the film). Only with the correct density or blackening of the film can an x-ray be read correctly. (There are other factors as well which are not considered in this example such as contrast, film speed, grid, etc). The radiographer has control over the density of the film by adjusting either the distance or by adjusting the mAs (milliamp seconds, the number of milliamperes and the number of seconds duration of the x-ray).

The relationship between the distance and mAs can be described by the quadratic equation

\[
\frac{mAs_1}{mAs_2} = \frac{D_1^2}{D_2^2}
\]

(known as the direct square law in radiology)

Where: \[mAs_1 = \text{original mAs} \quad mAs_2 = \text{new mAs} \]
\[D_1 = \text{old distance} \quad D_2 = \text{new distance}.\]

**Question:** If a satisfactory x-ray is obtained with 20 mAs (milliamp seconds) at 72", what level of mAs will be required to maintain the same quality at 40"?

**Answer:** First write down what we are given. \[mAs_1 = 20, D_1 = 72, \text{ and } D_2 = 40.\]

Now substitute these values into the equation above and we get,

\[
\frac{20}{mAs_2} = \frac{72^2}{40^2}. \quad \text{We can use our calculators to simplify the right hand side of the equation and get, } \frac{20}{mAs_2} = 3.24.
\]

We can now multiply both sides of the equation by \[mAs_2\] and get:

\[
mAs_2 = \frac{20}{3.24} \approx 6.18.
\]
to get, $20 = 3.24mAs_2$. Finally, divide by 3.24 to get, \[ \frac{20}{3.24} = mAs_2 \]. Now using our calculators we get $mAs_2 = 6.17$. Thus, the radiographer should set the $mAs$ to 6.17 for the same quality output.

**Support in the Literature:**

Focusing on learning rather than teaching requires that instructors rethink our role as well as the role of students in the learning process. To accomplish this, Huba and Freed (3) believe we must challenge our basic assumptions about how people learn and what the roles of a teacher should be. In other words, we must experience a paradigm shift. In the learner-centered paradigm, students construct knowledge through gathering and synthesizing information and integrating it with the general skills of inquiry, communication, critical thinking and problem solving. Students are actively involved and the instructor’s role is to coach and facilitate where teaching and assessing are intertwined and everyone learns together.

Information published in 1996 by the Education Commission of the States (4) noted that “Students learn better when engaged in a team effort rather than working on their own ... it is the way the world outside the academy works.” (Education Commission of the States, 1996, p. 8). Unlike conventional methods of instruction where students are often graded on a competitive basis, learner-centered classrooms provide opportunities for students to work together and develop their skills in teamwork and cooperation, thus deepening their knowledge and understanding.

Research suggests that “the more time and effort students invest in the learning process and the more intensely they engage in their own education, the greater will be their growth and achievement, their satisfaction with their educational experiences, and their persistence in college, and the more likely they are to continue learning.” (Study Group on the Conditions of Excellence in American Higher Education, 1984, p. 17).

Assessment techniques also need to be incorporated to help students learn to become more effective learners. (Angelo and Cross, 6) have developed a number of classroom assessment techniques (CATs) to help faculty to better understand and promote learning. These techniques increase our ability to help students become more effective, self-assessing, self-directed learners. The quality of student learning is directly, although not exclusively, related to the quality of teaching and, to improve the effectiveness, teachers need first to make their goals and objectives explicit and then receive appropriate and focused feedback early and often.

According to Pierce & Jones (7), “PBL promotes cognition growth,
which places an emphasis on higher-level thinking, knowledge transfer, collection and information analysis, and synthesis of information from multiple sources and viewpoints” (1998, p. 79). This makes PBL an excellent tool to enrich the learning environment and simulate real world problems that students will eventually have to relate to when they enter a profession. It makes us ask the basic educational question: Are we using content in meaningful ways to increase learning and retention? (7)

Our Experience

It has been our experience that PBL should be introduced in the developmental mathematics courses as well as college level mathematics courses. However, it should be understood that problem based learning is just one method to enhance the learner centered environment, and is not the only instructional tool that an instructor may choose to utilize. Creating a course tier method of PBL would allow the acquisition of better problem solving skills as students progress to higher levels of mathematics.

At our institution, a FIPSE grant allowed us to coordinate and institute PBL in mathematics and allied health. Nine faculty and 700 students were involved. The strategy involved allied health instructors from different disciplines and mathematics instructors to sit in on each other’s classes for a semester to better understand the material prior to writing any specific high end or low-end problems. The objective of this grant was to increase the amount of developmental mathematics coursework that directly relates to nursing, respiratory therapy, radiology, physical therapy, and occupational therapy during the third project year to at least 70%. All instructors in PBL classes adopted the same tests. The problems, once developed were incorporated into a supplemental book, which was used by the mathematics faculty in the developmental mathematics classes. The supplemental mathematics book did not replace the mathematics class text, but allowed the students to apply mathematics in a problem-based approach using real world scenarios. Although the majority of the problems in the supplemental mathematics book were geared towards allied health curriculums, all students could still test their problem solving skills by utilizing these concepts. As a result, students who enrolled in PBL classes performed better in a statistically significant sense (0.001 level) on a post-test exam than students enrolled in the regular mathematics classes. These students also rated their improvement in teamwork skills as better.

It was important that both the allied health faculty and the mathematics faculty cross-trained in each other’s classes to better understand the cooperative endpoint each team was reaching to achieve. The published
PBL mathematics textbook is a collaborative effort that incorporates the acquisition of knowledge achieved by both the mathematics and allied health faculty. The faculty that participated in this grant reported that they enjoyed the experience and the opportunity to either brush up on "shaky" mathematics skills or to learn something outside of their own discipline.

From our viewpoint and experiences with this method, we feel that PBL enhances the learning environment, and is an excellent supplement to traditional instructional methods. Some authors are steadfast that PBL should entirely replace the traditional classroom techniques, however, our experience suggest that both methods when combined and balanced create a better environment for learning and retention of material.

No one methodology works all the time and a teacher must be prepared to vary the methods of instruction and actively engage the students. Activities and any other classroom materials must be flexible in order to accommodate all learning styles. While there are limits to infusing PBL into a curriculum, the benefits are many, and the approach should be able to be applied to many other disciplines.

Students taking the initiative to learn is the first step in the solution to any problem. PBL lays a good foundation for these types of skills acquisitions, and it is a great way to incorporate aspects of learning not normally taught in the traditional curricula today.

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References


