Running head: PROBLEM-BASED LEARNING

Problem-Based Learning

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We are all probably familiar with Thomas Edison's oft-quoted statement "Genius is 1 percent inspiration and 99 percent perspiration" (Moncur, n.d.). Another of his quotes which may not be so familiar is "I have not failed. I've just found 10,000 ways that won't work" (Moncur, n.d.). This goes to the central theme of Edison's life, which is that every hardship in life is a problem to be solved, and every invention he pursued is meant to be a solution to a problem. Edison knows that true learning comes as a result of trying to solve a problem (Bellis, 2005). This is also the central theme of the problem-based learning instructional strategy, which is to develop deeper understanding and longer retention of knowledge through the process of solving a problem. The goal of this paper is to provide the reader with a basic understanding of problem-based learning, as described in a sample of literature available on the topic.

Review of the Literature

Savin-Baden (2000), as well as many others, attributes the popularization of problem-based learning to Barrows and his research beginning in the 1960s on the reasoning abilities of medical students. Since that time, Barrows' model "has been refined and implemented in over sixty medical schools" (Savery & Duffy, 2001, p. 5). The model has also been adopted in many other fields, including business education, architecture, law, engineering, psychology, social work, and high school. The literature reviewed for this paper comes from three fields of education: (a) medical, (b) business, and (c) secondary mathematics.

The three fields seem to agree on the characteristics of using problem-based learning strategies, which include: (a) developing a collection of problems for each course, (b) choosing appropriate tasks that are authentic tasks and designed to reflect the complexity of the environment learners will move to next, (c) planning for suitable amounts of time for learners to work on the problems, (d) preparing the teacher to fulfill the facilitator's role (must be able to give the learner ownership of the process), and (e) developing classroom management routines and providing an appropriate learning environment (Barrows, 1986; Erickson, 2003; Johnstone & Biggs, 1998; Savery & Duffy, 2001). It is interesting to note some of the differences between the fields. For instance, in business education it is common to see a problem such as "Should AT&T buy NCR?" for which the students have an entire semester to find their solution (Savery & Duffy, 2001). In medical school courses, problems are more likely to last for one to three weeks and are generally structured as a patient presenting with specific symptoms (Kanter, 1998). In mathematics education, especially in secondary schools, the literature indicates that most problems are designed to be worked on in one or two class periods (Erickson, 2003; Holliday & Duf, 2004). Specific literature from each of the three fields is now presented.

Medical Education

As note earlier, problem-based learning has its origins in medical education and has been used in medical schools for over 20 years. There has been ample opportunity to comment on the theory of problem-based learning and to study its effects as compared to more traditional methods of medical education. As a result, the literature in this field is quite extensive. A search for "problem-based learning" on the PubMed database returned 2,407 entries. Of particular interest are a few articles regarding studies on the effectiveness of problem-based learning.

Vernon and Blake (1993) have performed a meta-analysis to review all evaluative research that compares problem-based learning with more traditional methods of medical education from 1970 through 1992. Their review covers 35 studies representing 19 institutions. Problem-based learning is found to be significantly better with respect to the students' attitudes and opinions about the programs and measures of the students' clinical performance. Traditional students are found to perform better on the National Board of Medical Examiners Part I test. In general, the results support the conclusion that problem-based learning is better than traditional methods.

Two more recent studies seem to contradict those findings. Colliver (2000) focuses on the credibility of claims about the ties between problem-based learning and education outcomes and the magnitude of the effects. He concludes, based on a review of the literature, that there is no convincing evidence of improved knowledge or clinical performance, and especially not to the degree that would be expected given the resources required by a problem-based learning curriculum.

Herzig, Linke, Marxen, Borner, and Antepohl (2003) provide more recent results with respect to small-scale exposure to problem-based learning. They follow a group of third-year medical students who are randomly assigned to either a problem-based learning course or a lecture-based learning course on the same topic. At two different intervals after the initial courses, students are retested on the subject matter. No significant differences are found, and Herzig et al. (2003) conclude that a small-scale exposure to problem-based learning does not significantly change long-term presence of factual knowledge.

Business Education

As noted in Savery and Duffy (2001), business school MBA programs have begun to adopt problem-based learning. Earlier, the sample problem "Should AT&T buy NCR?" is presented. One of the challenges in using problem-based learning in business schools is keeping the problems *real*. While medical schools do have new diseases and conditions that students need to learn about, problems based on a patient with symptoms of influenza, broken bones, stroke, heart disease, or high blood pressure can be used again and again, since it is likely there will always be patients with those conditions. However, the “Should AT&T buy NCR?” problem is probably no longer useful, since neither company exists in the same form as they did at the time the question was relevant. The business schools must constantly work to come up with new questions that address current business issues. These real problems tend to engage the learner more. Also, using real problems makes it possible for students to know the outcome of the problem, for example, did AT&T buy NCR.

Johnstone and Biggs (1998) propose the use of problem-based learning specifically for accounting students. In medical education, problem-based learning is used during the first two years of medical science curricula (Savery & Duffy, 2001). In contrast, Johnstone and Biggs propose that “problem-based learning methods should be implemented only after basic technical accounting knowledge has been acquired” (¶ 3). They go on to recommend “limited application of problem-based learning during the first four years and more extensive application during the fifth year of the curriculum” (¶ 4). This recommendation is consistent with Milne and McConnell (2001), who conclude that problem-based learning approaches are most suited to bridging the gap between education and life as a professional.

Breton (1999) actually performs a study on the effects of two different teaching methods used to teach an accounting theory class. The first method is the traditional lecture style, along with assignments and tests. The second method is a problem-based learning approach. Breton reports that significant differences in the final exam scores are found between the two groups, with the problem-based learning group having better scores on most questions. The problem-based learning group also reports the perception that they acquired better and longer lasting knowledge.

Mathematics Education

The National Council of Teachers of Mathematics (NCTM) has decided that problem solving is an important and necessary part of mathematics education, since problem solving is named as one of the Process Standards in the *Principles & Standards for School Mathematics* (*PSSM*) (NCTM, 2000). In the description of the Problem Solving standard, NCTM stresses the importance of problem-based learning when they say “Solving problems is not only a goal of learning mathematics but also a major means of doing so” (NCTM, 2000, p. 51). Similar to how Johnstone and Biggs (1998) recommend that problem-based learning be utilized after basic accounting knowledge has been acquired, the *PSSM* says “Problem solving can and should be used to help students develop fluency with specific skills” (NCTM, 2000, p.52).

Erickson (2003) agrees with the NCTM’s recommendation to teach mathematics in a way that promotes higher-level thinking, as well as a positive disposition towards math, and proposes problem-based instruction as a teaching strategy that would work to that end. She provides an example of a task, an introductory exploration of geometric sequences, and several methods to perform the task that employ problem-based learning strategies, and discusses which types of learners might prefer each method. She also provides examples of other problem-based learning activities that have been developed for other mathematical topics.

Statement of the Current Situation and Discussion of the Findings

This author does not yet have a classroom of his own, so it is not possible to provide a first-hand report on the current situation of the use of problem-based learning in the classroom. However, this author has had several opportunities to teach lessons in high school classrooms, and to discuss the situation with current teachers. After completing a problem-based lesson in a statistics class, the regular teacher tells me "I remember studying problem-based learning in college, but there's so much pressure to *cover the material* in most of the classes I've taught, that I never felt like I had the opportunity to incorporate problem-based lessons." In this teacher's case, the demands of either high-stakes tests (e.g. SAT, AP, CRCT, GA Graduation Test) or end-of-course tests dictated that she stick to the material in the texts being used, and that taking time for a problem-based lesson is a luxury that cannot be afforded.

In a separate conversation with a high school geometry teacher, we discuss using *Geometer's Sketchpad* as a way for students to discover various geometric properties and their mathematical counterparts, such as the Pythagorean Theorem. The teacher agrees that some students would probably remember the concept better if allowed to discover it on their own, but says "it's just not practical to spend an entire block letting the students *discover* the Pythagorean Theorem, when I can spend 15 minutes writing it up on the board and working several examples." He goes on to explain that he feels there is just too much material to cover to spend so much time in the lab.

These teachers appear to suffer from the misconception that problem-based learning has only one structure and that the structure dictates "big problems" that take a "long time" to solve. In contrast, Barrows (1986) describes a taxonomy of problem-based learning methods. The taxonomy can be used to facilitate an awareness of the many variations in quality of method and the educational objectives that can be achieved. The teacher can use the taxonomy to help choose a problem-based learning method most appropriate for his students and his teaching abilities.

Based on the volume and content of literature regarding problem-based learning in the medical education field, the current situation there seems to be that problem-based learning has been of great value, and its use is going to continue. The business education literature also seems to indicate that problem-based learning has value, although that field does not seem to be embracing problem-based learning as openly and thoroughly as medical education. As discussed earlier, and based on the fact that there is much less literature available, the use of problem-based learning in the mathematics education field seems to be an emerging trend.

Summary and Conclusions

It is interesting to note that none of the literature reviewed referred to problem-based learning as something easy to implement. The literature says that problems must be carefully constructed and kept up to date, a learning environment must be provided to promote information gathering and self-directed learning, and teachers must learn how to become tutors and facilitators. It all sounds like a lot of hard work.

Thomas Edison is also a student of human nature and notes “There is no expedient to which a man will not go to avoid the labor of thinking” (Moncur, n.d.). This seems to indicate that when faced with something that requires a lot of hard mental work, such as implementing problem-based learning, people tend to avoid it. Luckily, pioneers in the problem-based learning field, such as Barrows, are able to recognize the gains to be made in a critical field such as medical education, and are willing to put in the effort. Business schools, whose financial survival hinge on the quality of their graduates, also seem to be putting in the effort to implement problem-based learning.

Unfortunately, this author does not believe the outlook is as good for the implementation of problem-based learning in secondary mathematics. Edwards (2000) notes that teachers participating in an education reform study needed to participate in a problem-based learning activity in order to get a vision of how problem-based activities could be used. So, it is reasonable to expect that in order for the use of problem-based learning to grow in secondary mathematics education, it must first be used more extensively in the college-level teacher education and/or professional development of secondary mathematics teachers. This author's experience has been that problem-based learning is not extensively used in college-level mathematics courses, and that not enough in-service teachers pursue the type of professional development that would expose them to problem-based learning techniques. Schools of education need to push harder for the implementation of problem-based learning in college math departments, and public school leaders need to push harder for meaningful professional development, in order for problem-based learning to spread in secondary mathematics education.

One positive outlook in the adoption of problem-based learning is the potential for appropriate questions to be included in the textbooks adopted by secondary school systems. Medical school texts, such as *Genomes* (Brown, 2002), include sections of problem-based learning questions at the end of each chapter. If secondary mathematics textbooks start to include similar sections, then implementation of problem-based learning should accelerate, just as the use of graphing calculators in the classroom accelerated when textbooks started including calculator-based activities.

The "learning environment infrastructure" at all educational institutions also needs to change. In particular, libraries and computer labs need to structure the services they provide to facilitate the information gathering and self-directed learning phases of the problem-based learning process. Facilities need to be provided where the small learning groups can meet, with access to resources, and safe places to store work-in-progress.

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