ED482725 2003-00-00 Problem-Based Learning in Mathematics. ERIC Digest.

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ERIC Identifier: ED482725
Publication Date: 2003-00-00
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Source: ERIC Clearinghouse for Science Mathematics and Environmental Education Columbus OH.

Problem-Based Learning in Mathematics. ERIC Digest.

Problem-Based Learning (PBL) describes a learning environment where problems drive the learning. That is, learning begins with a problem to be solved, and the problem is posed is such a way that students need to gain new knowledge before they can solve the problem. Rather than seeking a single correct answer, students interpret the problem, gather needed information, identify possible solutions, evaluate options, and present conclusions. Proponents of mathematical problem solving insist that students become good problem solvers by learning mathematical knowledge heuristically. Students' successful experiences in managing their own knowledge also helps them solve mathematical problems well (Shoenfeld, 1985; Boaler, 1998). Problem-based learning is a classroom strategy that organizes mathematics instruction around problem solving activities and affords students more opportunities to think critically, present their own creative ideas, and communicate with peers mathematically (Krulik & Rudnick, 1999; Lewellen & Mikusa, 1999; Erickson, 1999; Carpenter et al., 1993; Hiebert et al., 1996; Hiebert et al., 1997).

PBL AND PROBLEM SOLVING

Since PBL starts with a problem to be solved, students working in a PBL environment must become skilled in problem solving, creative thinking, and critical thinking. Unfortunately, young children's problem-solving abilities seem to have been seriously underestimated. Even kindergarten children can solve basic multiplication problems (Thomas et al., 1993) and children can solve a reasonably broad range of word problems by directly modeling the actions and relationships in the problem, just as children usually solve addition and subtraction problems through direct modeling. Those results are in contrast to previous research assumptions that the structures of multiplication and division problems are more complex than those of addition and subtraction problems. However, this study shows that even kindergarten children may be able to figure out more complex mathematical problems than most mathematics curricula suggest. PBL in mathematics classes would provide young students more opportunities to think critically, represent their own creative ideas, and communicate with their peers mathematically.

PBL AND CONSTRUCTIVISM

The effectiveness of PBL depends on student characteristics and classroom culture as well as the problem tasks. Proponents of PBL believe that when students develop methods for constructing their own procedures, they are integrating their conceptual knowledge with their procedural skill.

Limitations of traditional ways of teaching mathematics are associated with teacher-oriented instruction and the "ready-made" mathematical knowledge presented to students who are not receptive to the ideas (Shoenfeld, 1988). In these circumstances, students are likely to imitate the procedures without deep conceptual understanding. When mathematical knowledge or procedural skills are taught before students have conceptualized their meaning, students' creative thinking skills are likely to be stifled by instruction. As an example, the standard addition algorithm has been taught without being considered detrimental to understanding arithmetic because it has been considered useful and important enough for students to ultimately enhance profound understanding of mathematics. Kamii and Dominick(1998), and Baek (1998) have shown, though, that the standard arithmetic algorithms would not benefit elementary students learning arithmetic. Rather, students who had learned the standard addition algorithm seemed to make more computational errors than students who never learned the standard addition algorithm, but instead created their own algorithm.

STUDENTS' UNDERSTANDING IN PBL ENVIRONMENT

The PBL environment appears different from the typical classroom environment that people have generally considered good, where classes that are well managed and students get high scores on standardized tests. However, this conventional sort of instruction does not enable students to develop mathematical thinking skills well. Instead of gaining a deep understanding of mathematical knowledge and the nature of mathematics, students in conventional classroom environments tend to learn inappropriate and counterproductive conceptualizations of the nature of mathematics. Students are allowed only to follow guided instructions and to obtain right answers, but not allowed to seek mathematical understanding. Consequently, instruction becomes focused on only getting good scores on tests of performance. Ironically, studies show that students educated in the traditional content-based learning environments exhibit lower achievement both on standardized tests and on project tests dealing with realistic situations than students who learn through a project-based approach (Boaler, 1998).
In contrast to conventional classroom environments, a PBL environment provides students with opportunities to develop their abilities to adapt and change methods to fit new situations. Meanwhile, students taught in traditional mathematics education environments are preoccupied by exercises, rules, and equations that need to be learned, but are of limited use in unfamiliar situations such as project tests. Further, students in PBL environments typically have greater opportunity to learn mathematical processes associated with communication, representation, modeling, and reasoning (Smith, 1998; Erickson, 1999; Lubienski, 1999).

TEACHER ROLES IN THE PBL ENVIRONMENT

Within PBL environments, teachers' instructional abilities are more critical than in the traditional teacher-centered classrooms. Beyond presenting mathematical knowledge to students, teachers in PBL environments must engage students in marshalling information and using their knowledge in applied settings.
First, then, teachers in PBL settings should have a deep understanding of mathematics that enables them to guide students in applying knowledge in a variety of problem situations. Teachers with little mathematical knowledge may contribute to student failure in mathematical PBL environments. Without an in-depth understanding of mathematics, teachers would neither choose appropriate tasks for nurturing student problem-solving

strategies, nor plan appropriate problem-based classroom activities (Prawat, 1997; Smith III, 1997).

Furthermore, it is important that teachers in PBL environments develop a broader range of pedagogical skills. Teachers pursuing problem-based instruction must not only supply mathematical knowledge to their students, but also know how to engage students in the processes of problem solving and applying knowledge to novel situations. Changing the teacher role to one of managing the problem-based classroom environment is a challenge to those unfamiliar with PBL (Lewellen & Mikusa, 1999). Clarke (1997), found that only teachers who perceived the practices associated with PBL beneficial to their own professional development appeared strongly positive in managing the classroom instruction in support of PBL.

Mathematics teachers more readily learn to manage the PBL environment when they understand the altered teacher role and consider preparing for the PBL environment as a chance to facilitate professional growth (Clarke, 1997).

CONCLUSIONS

In implementing PBL environments, teachers' instructional abilities become critically important as they take on increased responsibilities in addition to the presentation of mathematical knowledge. Beyond gaining proficiency in algorithms and mastering foundational knowledge in mathematics, students in PBL environments must learn a variety of mathematical processes and skills related communication, representation, modeling, and reasoning (Smith, 1998; Erickson, 1999; Lubienski, 1999). Preparing teachers for their roles as managers of PBL environments presents new challenges both to novices and to experienced mathematics teachers (Lewellen & Mikusa, 1999).

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SELECTED ERIC RESOURCES

The ERIC database can be electronically searched online at: http://www.eric.ed.gov/searchdb/index.html. To most effectively find relevant items in the ERIC database, it is recommended that standard indexing terms, called "ERIC Descriptors," be used whenever possible to search the database. Both "problem based learning" and "problem solving" are ERIC descriptors, so these would be good terms to use in constructing an ERIC search. Following are some sample items that are included in the ERIC database:

Delisle, R. (1997) "How to use problem-based learning in the classroom." Alexandria, VA: Association for Supervision and Curriculum Development. [ED 415 004]

This book shows classroom instructors how to challenge students by providing them with a structured opportunity to share information, prove their knowledge, and engage in independent learning.

Ulmer, M. B. (2000). "Self-grading: A simple strategy for formative assessment in activity-based instruction." Paper presented at the Conference of the American Association for Higher Education, Charlotte, NC. [ED 444 433]

This paper discusses the author's personal experiences in developing and implementing a problem-based college mathematics course for liberal arts majors. The paper addresses concerns about increased faculty workload in teaching for critical thinking and the additional time required for formative assessment.

van Biljon, J. A., Tolmie, C. J., du Plessis, J. P.. (1999, January). Magix-An ICAE System for problem-based Learning. "Computers & Education," 32 (1), 65-81. [EJ 586 410]

Discussion focuses on Magix, a prototype ICAE system for use in problem-based learning of linear mathematics for 10- to 12-year olds. The system integrates the principles of constructivism, user-driven interaction, knowledge-based systems, and metacognition.

Erickson, D. K. 1999, September). A problem-based approach to mathematics instruction. "Mathematics Teacher," 92 (6), 516-21. [EJ 592 083]

This article describes preparation for instruction using a problem-based approach as part of a teaching-strategy repertoire. Suggestions of ways that mathematics teachers can get assistance in successfully implementing a problem-based teaching approach are included. Research results indicate what students are likely to accomplish in such classes.

This digest was funded by the Office of Educational Research and Improvement, U.S. Department of Education, under contract no. ED-99-CO-0024. Opinions expressed in this digest do not necessarily reflect the positions or policies of OERI or the U.S. Department of Education.

Title: Problem-Based Learning in Mathematics. ERIC Digest.
Document Type: Information Analyses---ERIC Information Analysis Products (IAPs) (071); Information Analyses---ERIC Digests (Selected) in Full Text (073);
Target Audience: Practitioners, Teachers

Descriptors: Active Learning, Elementary Secondary Education, Experiential Learning, Learning Strategies, Mathematics Instruction, Problem Based Learning, Problem Solving
Identifiers: ERIC Digests