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Dr. Kriner Cash, Superintendent of Schools
Dr. Genelle Morris, Chief Accountability Officer

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Ruzanna Topchyan, Ph.D., Program Evaluator

Problem-Based Learning

AT A GLANCE

Problem-based learning (PBL) is an instructional approach that has been used successfully for over 30 years and continues to gain acceptance in multiple disciplines. It is a learning-centered approach geared towards empowering learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to defined problem. PBL, as it is generally known today, evolved from innovative health sciences curricula introduced in North America over 30 years ago and l has been implemented in several areas of higher education, including medicine, business, education, architecture, law, engineering and social work as well as in K-12. The purpose of this capsule is to present PBL as an instructional approach, and taxonomy, the debate over PBL effectiveness, and sample research studies on PBL effectiveness.

Problem Based Learning as an Instructional Approach and Taxonomy

As an instructional approach, PBL affords learners to face ill-structured problems in an ill-structured and ever-expanding domain that requires lifelong learning skills. It combines the teacher-directed case method with the discovery learning philosophy of Jerome Bruner. PBL creates opportunities for active learning, which is reported to lead to increases in students' performance on examination and to raise average grades by a half a letter, and that failure rates under traditional lecturing increase by 55% over the rates observed under active learning (Savery, 2015).

Due to the large number of PBL models an attempt was made to create a taxonomy. For instance, Barrows (1986) proposed a taxonomy that classified PBL into six categories using two variables with three levels. The two variables are the degrees of self-directedness and problem structuredness. The researcher further defined the three levels for the variable of self-directedness as (1) teacher-directed, (2) student-directed, and (3) partially student- and teacher-directed. Hmelo-Silver (2004) also discussed three PBL instructional approaches (PBL, anchored instruction, and project-based sciences) in terms of their format and the tools used, such as the role of problems and the role of teachers. Furthermore, Harden and Davis (1998) devised a comprehensive categorization of 11 steps (or levels) of PBL models that fall into a spectrum of instructional approaches (ranging from theoretical learning to task-based learning) with different levels of problem-driven or lecture-driven instruction, as well as the order of teaching concepts and problems.

Debate over Problem Based Learning

Many have addressed the advantages of using the Problem-Based Learning model in instruction. In their research-based book *Problems as Possibilities: Problem-Based Learning for K-12 At Elementary Level*, Torp and Sage (1998) discussed several advantages of PBL for learners at different levels of education (elementary school, middle school and high school). From their perspective, PBL can teach students to think before rushing and completing an activity, predict if they can be helpful to resolve the problem, learn new interdisciplinary information, relate classroom content to real life situations and learn by doing, become real active participants in the world around them when they get the opportunity, learn additional skills while working on a problem, improve their behavior because PBL teaches how to deal with conflicts, and actively ask questions. It was also suggested that in PBL if problems are chosen that relate students' interest and concern they will lean better (e.g. role of power in grade 8^{th}). Dealing with authentic problems helps students think about ethical aspects of issues they might not have otherwise considered. Students can discover skills that they did not know they had previously. High school students find that PBL teaches not only *what* (content) but also *how* (skills), and find PBL beneficial in preparing them for their future. PBL can enhance learning of content. It was stated that PBL could be especially effective for students with special needs who might not want to learn or find it difficult to learn unless they see a reason behind the lesson and students with different learning styles because it allows students to use the learning style that is best for them. Furthermore, PBL allows students to demonstrate their knowledge through many different assessment formats, such as oral presentations, debates, and posters.

However, despite all the above listed advantages that PBL can afford learners, the question that is still being debated is: *Is PBL effective?* A number of meta-analyses (e.g. Albanese and Mitchell 1993; Berkson 1993; Colliver 2000; Neville 2009) examined the effect of PBL on various aspects of students learning outcomes, such as domain knowledge acquisition, problem solving skills, self-directed learning, group processing, and social and psychological soft skills. However, the results from the meta-analyses were not conclusive, even yet, conflicting. Some researchers suggested that PBL may not be effective in all aspects of student learning, but is especially effective in certain aspects of its instructional emphases and characteristics. For example, there has been a general agreement that PBL is effective in promoting students' problem solving skills (e.g., Albanese and Mitchell 1993; Dabbagh and Denisar 2005; Strobel and van Barneveld 2009). However, the systematic review of the long-term effects of PBL conducted by Koh, Khoo, Wong and Koh (2008) indicated otherwise. It seems that the difference in opinions stems from the lens that research uses to look at PBL effectiveness. As Hung (2011) mentioned, the difference in the opinions above seem to originate from the fact that previous research efforts appeared to debate the two ends of the instructional process—the theoretical conception and student learning outcomes—without discussing the processes, that is the implementation of PBL.   The assessment of student learning outcomes (i.e., final test scores or board exams) provides us with only an end-result depiction of the interactions of all the variables involved in the implementation process, as well as the interaction between the theoretical conception and the reality.

Taxonomy of PBL Models

A number of researchers have attempted to classify the PBL models. For instance, Barrows (1986) proposed a taxonomy that classified PBL into six categories using two variables with three levels. The two variables are the degrees of self-directedness and problem structuredness. The three levels for the variable of self-directedness were further defined as (1) teacher-directed, (2) student-directed, and (3) partially student- and teacher-directed. Harden and Davis (1998) devised a comprehensive categorization of 11 steps (or levels) of PBL models that fall into a spectrum of instructional approaches (ranging from theoretical learning to task-based learning) with different levels of problem-driven or lecture-driven instruction, as well as the order of teaching concepts and problems. Furthermore, Hmelo-Silver (2004) also discussed three PBL instructional approaches (PBL, anchored instruction, and project-based sciences) in terms of their format and the tools used, such as the role of problems and the role of teachers.

Empirical Research on PBL Effectiveness

Recent studies conducted on PBL attempted to identify PBL effectiveness from a number of angles some of which are: (i) in relation to traditional instruction, (ii) for active learning, (iii) for concept learning, (iv) for learning in STEM, (v) in flipped classroom, and (vi) for overall student growth. Sample studies are below.

PBL vs. Traditional Instruction

Yadav, Subedi, Lundeberg and Bunting (2011) reported a study that investigated impact of problem-based learning (PBL) on undergraduate electrical engineering students’ conceptual understanding and their perceptions of learning using PBL as compared to lecture. The results of the study suggested participants’ learning gains from PBL were twice the gains from traditional lecture format.

Wijniaa, Loyensa and Derousa (2011) reported a study that examined the effects of two learning environments (i.e., problem-based learning [PBL] versus lecture-based [LB] environments) on undergraduates’ study motivation. Survey results demonstrated that PBL students scored higher on competence but did not differ from LB students on autonomous motivation. Analyses of focus groups further indicated that active learning aspects, such as collaboration are perceived as motivating.

Horak and Galluzzo (2017) reported a quasi-experimental study the purpose of which was to explore student achievement and students' perceptions of classroom quality in being instructed through PBL and traditional instruction. The results of the study suggested that although there were statistically significant gains in both groups, the gain score in the PBL group was higher. Additionally, the findings revealed statistically significant differences in the total score on the Student Perceptions of Classroom Quality (SPOCQ) in favor of the PBL group.

Bergstrom, Pugh, Phillips, and Machlev (2016) reported a study that investigated the effectiveness of PBL in relation to traditional instruction with respect recognition learning and transfer and conducting an aptitude-treatment interaction analysis. The results of the study suggested that students in the PBL condition performed significantly better than students in the lecture/discussion condition on a transfer measure and equally on a recognition learning measure.

PBL and Active Learning

Belland, Glazewski and Richardson (2010) examined the use of computer-based argumentation scaffolds, called the *Connection Log*, to help middle school students build evidence-based arguments under PBL. Data sources included a test of argument evaluation ability, persuasive presentation rating scores, informal observations, videotaped class sessions, and retrospective interviews. Results of the study suggested a significant simple main effect on argument evaluation ability among lower-achieving students, and use of the scaffolds by the small groups to communicate and keep organized.

Freeman et al. (2014) conducted a meta-analysis on 225 studies to test the hypothesis that lecturing maximizes learning and course performance. They reported data on examination scores or failure rates when comparing student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses under traditional lecturing versus active learning. The effect sizes indicate that on average, student performance on examinations and concept inventories increased by 0.47 SDs under active learning (n = 158 studies), and that the odds ratio for failing was 1.95 under traditional lecturing (n = 67 studies). Average examination scores, on the other hand, improved by about 6% in active learning sections, and students in classes with traditional lecturing were 1.5 times more likely to fail than were students in classes with active learning.

PBL and Concept Learning

Padmavathy and Mareesh (2013) examined the effectiveness of PBL in teaching the concepts of mathematics education at middle school level. Randomized control group pretest and posttest experimental design was used for the study. Findings of the study revealed that PBL had effect in teaching mathematics and improved students understanding and ability to use concepts in real life.

Wirkala and Kuhn (2011) reported a highly controlled experimental study that compared students learning the same material under three instructional conditions: lecture/discussion, characteristic small-group PBL, and solitary PBL. Assessments of comprehension and application of concepts in a new context nine weeks after instruction showed superior mastery in both PBL conditions, relative to the lecture condition, and equivalent performance in the two PBL conditions, the latter indicates that the social component of PBL is not a critical feature of its effectiveness.

PBL and STEM

Lou, Shih, Diez and Tseng (2011) reported a study that explored the effects PBL strategies on the attitudes of female senior high school students toward integrated knowledge learning in science, technology, engineering, and mathematics (STEM). The results of the study suggested: (1) PBL strategies can be helpful in enhancing students' attitudes toward STEM learning and the exploration of future career choices; (2) PBL teaching strategy helped to lead students step by step toward completing the contest's mission and to experience the meaning of integrated STEM knowledge; (3) not only can students actively apply engineering and science knowledge, but they also tend to gain more solid science and mathematics knowledge through STEM learning in PBL; and (4) PBL can enhance students' abilities and provide them experiences related to knowledge integration and application.

Rehmat (2015) reported about a quasi-experimental mixed methods study conducted with 98 fourth grade students. Students were randomly assigned to PBL and traditional instruction. The study utilized STEM content assessments, a standardized critical thinking test, STEM attitude survey, PBL questionnaire, and field notes from classroom observations to investigate the impact of problem-based learning on students' content knowledge, critical thinking, and their attitude towards STEM. Subsequently, it explored students' experiences of STEM integration in a PBL environment. The quantitative results revealed a significant difference between groups in regards to their content knowledge, critical thinking skills, and STEM attitude. From the qualitative results, three themes emerged: *learning approaches, increased interaction*, and *design and engineering implementation*. The students in PBL group seemed to described the PBL environment to be highly interactive that prompted them to employ multiple approaches, including design and engineering to solve the problem

PBL in Flipped Classroom

Tsai, Shen and Lu (2015) reported a quasi-experimental study that explored the effects of problem-based learning with flipped classroom that used PBL (FPBL) on the development of students' learning performance. Students in the study were assigned to three groups FPBL, PBL and control group (traditional instruction). The results of the study suggested that the effect of FPBL on improving students' learning performance was significantly higher than other teaching methods investigated.

PBL and Student Overall Growth

Safavi (2016) reported a study that measured the growth of middle school science students in overall interest, awareness, and content knowledge regarding environmental issues, while applying PBL methods. The study used as before and after treatment questionnaire. The results of the study suggested that the application of PBL strategies did have positive impact on increasing students' understanding of how science relates to their everyday lives as well as empowering them have an active role in improving environmental conditions locally and globally. In addition, students enjoyed the ownership they felt toward their learning in cooperative and collaborative group discussions. The result of the study also indicated students' growth in knowledge and awareness toward renewable sources of energy and how they can be used to reduce human footprint in global climate change.

Conclusion

For any instructional approach or model to be evaluated as effective, its implementation based on the guidelines derived from the theory is equally important. As it was discussed above, the effectiveness of PBL is still being debated. However, there is also empirical evidence of the benefits that students receive if looked at them through all the different angles discussed above. The truth is that PBL models have been developed and implemented to meet the specific instructional needs of institutions or learner populations. These suggested PBL models are quite different in terms of the nature of problem solving and the degree of self-directed learning, which theoretically should result in different type of learning outcomes. When PBL models are implemented in different educational settings, a number of factors such as the nature of the disciplines, the learning goals, and the cognitive readiness or self-directed learning skills of the students need to be taken into consideration. Taking the criticism made to the large body of PBL research, which seems to be product oriented, it might be important to develop process approach to the evaluation of PBL evaluation.

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