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The Importance of Efficiency in Active Learning

Mehmet Şahin[1]

[1] Research Assist. Dr., Dokuz Eylül Unv., Buca Edu. Fac., Dept. of Sec. Sci. and Math. Edu., Buca-Izmir

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ABSTRACT

This study involves the factors that can be used to increase the efficiency of problem-based learning (PBL) and the importance of efficiency in PBL since it has commonly positive influences on learning and student attitudes. Recently, some universities in Turkey have begun to use this method. A literature review about the factors that affect learning in PBL classrooms has been carried out for the purpose of increasing its efficiency in teaching introductory physics and to see its positive influences on students' social skills and learning process. The following arguments were determined as possible factors that may positively affect the active learning process; i) forming small learning groups in PBL classrooms (instead of a single group), ii) integrating related disciplines at a sufficient level wherever appropriate in PBL modules, and iii) at every stage of the application of PBL, reviewing expectations from facilitators, instructors, teaching assistants (TAs), and other staff in PBL and reorganizing them if necessary.

Keywords: Active Learning, Problem Based Learning, Efficiency in Teaching

INTRODUCTION

Constructivist and sociocultural teaching and learning theories suggest that active participation has crucial importance in students' learning process (Açıkgöz, 2004; Bernhard, 2000; Edwards & Hammer, 2004). In constructivist learning approach, in essence, students construct actively their knowledge (Açıkgöz, 2004) by thinking, doing, and interactive experiences with the environment rather than passive receiver (Özel, 2005). This process was called as self-regulation by Zimmerman (1989). Self-regulation consists of sub-processes such as students' observation, evaluation, and the development of themselves. There are researches indicating that self-regulated learning has an influence on academic performance (Mace & Kratochwill, 1985). Among the basic aims of active learning methods are to enhance the conceptual learning of students, to provide students with different perspectives towards inquiry and research and help them gain creativity, and ensure the stability of knowledge. This is not a research study but a theoretical one presenting a literature review. Thus, the points highlighted in this study could be tested through empirical studies.

The purpose of this study is to seek answers for how to enhance the efficiency of active learning methods (particularly PBL) employed in many universities to teach introductory physics throughout the world. PBL is an active learning technique, so it uses active learning procedures. Students solve a real life problem usually working in groups. How students can work more efficiently, solve problems by conceptual understanding, and thus how they can achieve better learning are some of the questions that constituted a base for this study. A through literature review about basic components that may positively affect active learning process yielded some factors that can enhance students' success directly.

In the remaining parts of the study, first, a general framework for the active learning methodologies presented and some example programs involving active student participation in instruction are provided. Next, some information about PBL and the results of studies investigating the effects of PBL method are introduced. In the third part, the effects of group work, integration of disciplines, and facilitators in PBL classrooms are investigated via a literature review. Finally, in the light of the results of this study some implications and suggestions for improving the success of PBL approach are presented.

(I) Active Learning Methods

During the last two decades, in physics education, various active learning programs using constructivist approach have been developed in the USA. The common point of these programs was that they all encouraged active learning and students working together (American Association for the Advancement of Science, 1990). A basic principle of these models was to develop new learning strategies abating the factors that prohibit students from active participation in the learning process. One of the reasons that led researchers develop these programs was that physics education research has more and more revealed that students do not comprehend even the most basic concepts (Elby, 1999; Halloun & Hestenes, 1985a, 1985b; McDermott, 1984, 1991, 1993). As can be seen in the following examples, this method is applied in various ways. In some cases, laboratories were modified partially; in some universities, large classes were reformed to require students' active participation; and the most radical reformation was grouping instruction, labs, and problem solving sections into one class. Some of these programs, used to teach introductory physics, along with its developers and related references are given in Table 1 (adapted from Bernhard, 1999).

Table 1. Some Active Learning Approaches Used in Introductory Physics Instruction (Bernhard, 1999).

Curricula	Developer	Selected References
Discovery Labs		
Tools for Scientific Thinking	R. Thornton D. Sokoloff	Thornton, 1987, 1989
RealTime Physics	R. Thornton D. Sokoloff, and P. Laws	Thornton, 1997 Sokoloff, Thornton, & Laws, 1998
Socratic Dialogue Inducing (SDI) labs	R. Hake	Hake, 1992
Lecture Based Models		
Active Learning Physics System	A. van Heuvelen	van Heuvelen, 1991a, 1991b
Peer Instruction /Concept Tests	Eric Mazur	Mazur, 1997a, 1997b
Interactive Lecture Demos (ILD)	R. Thornton D. Sokoloff	Thornton, 1997 Sokoloff & Thornton, 1997

Table 1 Continued..

Recitation Based Models		
Co-operative Problem Solving	Ken and Pat Heller	Heller & Hollabaugh, 1992 Heller, Keith, & Anderson, 1992 Heller, Foster, & Heller, 1997
Tutorials in Introductory Physics	Lillian McDermott, *et al.*	McDermott, 1998 McDermott, Vokos, & Shaffer, 1997
Mathematical Tutorials	E. Redish, *et al.*	Redish, Saul, & Steinberg, 1997 Steinberg, Wittmann, & Redish, 1997
Full Studio Models		
Physics by Inquiry	Lillian McDermott *et al.*	McDermott, 1995 McDermott, Shaffer, & Vokos, 1997
Workshop Physics	Priscilla Laws	Laws, 1989, 1991, 1997
The Physics Studio	Jack Wilson	Wilson, 1994 Cummings, Marx, Thornton, & Kuhl, 1999
Scale-Up	Beicner *et al.*	http://www.ncsu.edu/per/scaleup.html

Studies carried out to evaluate these approaches (Hake, 1997; Saul & Redish, 1998) revealed that active learning programs improve students' problem solving abilities, especially in mechanics, enhanced students' understanding in conceptual problems and therefore resulted in more efficient physics classes than traditional lectures. Physics classes that incorporated active learning and traditional lecture were evaluated using *Force Concept Inventory* (FCI) and *Mechanics Baseline Test of Hestenes-Wells*. Hake (1997) analyzed the data obtained from more than 6000 students. Hake's analyses resulted that the efficiency of mechanics courses in the active learning classes increased more than the traditional ones. Even the weakest active learning classes performed better than the classes used traditional lecture.

The references in the preceding paragraph investigated the effects of active learning programs in a short time interval. That is, the evaluation tests or instruments were administered immediately after the class or at the end of the semester. However, some other research studies investigated the long-term effects of active learning on conceptual understanding and the success of active learning in teaching how to learn.

Francis, Adams and Noonan (1998) investigated the long-term learning effects of active learning in an algebra-based general physics course. An active learning program, *Tutorials in Introductory Physics*, replaced with the traditional physics labs. Conceptual tests were administered to students 1-3 years after the first administration. Students who have taken the first test were compared with the students who have taken the second one. Results showed that students who studied active learning methods performed only slightly less on the second test than they did in the first application. Therefore, researchers concluded that reformed courses achieved a fundamental change in students' conceptual knowledge structure.

Students from teacher education and civil engineering fields who studied *RealTime Physics* were administered FCI and Force and Motion Conceptual Evaluation Test 5 semesters after they took the course (Bernhard, 2000). According to the analyses of results of the tests administered 2.5 years after the instruction, students showed that they had at least the same amount of conceptual knowledge as they did in the first administration. Active learning programs employed in these studies aimed at changing students' wrong and biased physics concepts and ensuring students' active participation in the learning process.

Constructivist learning literature emphasizes that learning physics is much more complex than simply transferring knowledge from teacher to student (Osborne & Wittrock, 1985). Furthermore, physics learning is not an individual cognitive activity. Therefore, learning physics requires not only social application but also individual cognitive participation. New approaches employed in physics education indicated that teaching strategies that emphasize and apply cognitive participation, discussion, and collaborative learning effort help students attain the desired success rate (Crouch & Mazur, 2001; Hake, 1997).

(II) Problem-Based Learning (PBL)

PBL was first developed and applied at McMaster University in Canada (Barrows & Tamblyn, 1976, 1980). Shortly after, PBL applications were begun to be used in universities in Europe and Australia (Edwards & Hammer, 2004; Fink, Enemark & Moesby, 2002; Jones, 2006; Saarinen-Rahiika & Binkley, 1998). First applications of PBL had the purpose of providing medical students with a context to apply their knowledge and therefore they experience real life situations rather than simply learn the content of a course. Later, PBL became a popular learning approach especially in medicine, engineering, and education (Edens, 2000; Edwards & Hammer, 2004). PBL is defined as a teaching method that encourages learners to apply critical thinking and problem solving skills along with content knowledge to real life problems and issues (Levin, 2001). Since it relies on the assumption that learning takes place as a result of cognitive and social interaction in a context focused on a problem, PBL is an example of a constructivist pedagogic approach (Greeno, Collins & Resnick, 1996). In this approach, learning is more student-centered, and less teacher-directed. Learning is also an active process and students are responsible for their learning.

Students in small groups (~8 students) work on a single, open ended, real life problem, which is presented as a scenario to intrigue students' curiosity. Students try to solve the problem by producing hypotheses, testing and rejecting them, and determining the learning objectives, searching, learning, sharing, and discussing knowledge with the group. PBL emphasizes a learning community where each individual produces solutions to problems they face, has critical thinking skills, is a researcher, inquirer, open to change and development, and accepts life-long learning, rather than a community where learners depend solely on rote memorization and content knowledge (Güzeliş, Salk & Akgün, 2004).

(III) Efficiency in Active Learning

The most distinct feature of active learning is that it is learner-centered. Learners have the responsibility of their learning. Students have to determine their levels of knowledge, skills and abilities and set learning outcomes. With guidance, students learn how to learn, develop self-learning skills, and take an important step in attaining a life-long learning ability (Güzeliş, 2005). In the direction of determined aims, some already known and practiced applications could be applied more effectively in order to enhance the power of active learning. I will now explore these factors in the light of the related literature.

(a) Group Work as Active Learning

Cooperative learning has been investigated starting from 1980s to increase the success in education. Since then, a great deal of research have been published and presented in scientific journals and conferences throughout the world (Johnson, Johnson & Smith, 1991; Newmann & Thompson, 1987; Slavin, 1980, 1983). Cooperative learning involves learning strategies in which students work together. Related research indicates that cooperative learning methods promise better education by providing students with meaningful learning and fostering social and cognitive effort and common conscious. Cooperative learning methods are not new. They have been used for the most part of this century, especially in the USA. What researchers do is to plan and develop new strategies employing cooperative learning methods and apply them to new situations (Johnson, Johnson & Smith, 1991).

It may be argued that using cooperative learning within PBL may enhance the efficiency of PBL. Although PBL is carried out with small groups, these groups are more like a small class rather than a small group of 3-4 students. Groups in PBL classrooms can be further divided into 3-4 students and each group can work on the scenario separately.

It is crucial that groups should have social interdependence. Since students are evaluated individually, they will feel personal responsibility for their success as well as the group's. In cooperative learning, developing personal skills is as important as learning. Developing social skills, such as cooperation, plays a crucial role in group work. In most grouping strategies, to ensure students' positive cooperation, specific roles can be assigned within a group (such as reporter, moderator, encourager, and speaker, etc.) and roles can be exchanged among students in order for them to attain various skills in a group work (Smith & MacGregor, 1992). Among various group works, cooperative learning, PBL, peer teaching, and discussion groups can be mentioned. There can be a variety of activities in a cooperative work; however, what is essential here is students' inquiry, questioning, applying, and being actively involved in the learning process.

Experiences in PBL classrooms show that despite the small number of students in a class, some students still can not speak freely and openly, hesitate to communicate their ideas, and sometimes stay silent during an entire learning session. Facilitators can ask direct questions to these students and try to ensure their participation in the discussion, however, these kinds of approaches do not always work well and these students may not benefit from PBL (Johnson, Johnson & Smith, 1991).

Related research shows that the fear of speaking in front of a group of people is common among teenagers. Particularly university students may exhibit anxiety or shyness about speaking in front of a class. This kind of anxiety can be reduced significantly by allowing students to speak within groups with their friends (Johnson, Johnson & Smith, 1991). The research on cooperative learning has shown that cooperative learning situations encourage a realistic motivation, a continuous interest, and concentration on success, patience and stimulus for success as a group.

Mills, McKittrick, Mulhall and Feteris (1999) developed a learning strategy for the purpose of changing freshmen students' misconceptions in mechanics and improving their conceptual understanding. In this method, called *Conceptual Understanding Programme*, first students work on the problems individually, then they work in groups of three, and finally they discuss the proposed solutions to the problems whole class together. A facilitator who is trained for a short time for this purpose guides classes. Conceptual problems are usually chosen from daily life to focus on conceptual learning. Students participating in this program indicated that they enjoyed group work, they felt valued, found the opportunity to share, test, and evaluate their ideas and knowledge, and gained more conceptual knowledge than just memorizing a formula and solving a problem. Students were asked the question, "if there was a change in the course structure to help your understanding, what would be your preference of this change?" Most students replied to this question indicating their desire for more group work sessions. Two-third of the participating students indicated that group sessions helped them clear their ideas. This study emphasized that group work and strategic conceptual problems have important roles in understanding basic concepts.

If students are allowed to work in small groups in PBL classrooms, since they may positively encourage each other within the group, the efficiency of the courses and students' understanding may be improved. Each group member will force himself/herself to think and solve the problem, which in turn may enhance both his/her and group's success. Group members help and encourage each other in solving the problem and achieving the learning outcomes. Students reach learning outcomes via talking to other group members face to face, communicating their ideas openly, listening to and gaining from other members' ideas, and teaching each other.

(b) Synergy of Disciplines in Active Learning

Synergy involves the phenomenon where two or more distinct factors or influences performing together produce an effect greater than that created by only one of the individual influences. In PBL modules, concepts from different disciplines are integrated to help students learn the related concepts in a meaningful way in the context of each other. Much research has been conducted for more than three decades in the teaching of related science and mathematics concepts via integration (Brown & Wall, 1976; Education Development Center, 1969). Teaching mathematics, which is regarded as the language of science, together with other scientific disciplines not only enhances its learning but also helps students improve their understanding of both mathematics and science.

Many researchers investigating the relationships among the success in science and mathematics knowledge and ability believe that the success in science may depend on the understanding of mathematical concepts. Hudson and Rottmann (1981) examined the relationship between first semester physics students' (n=1043) final grades and their performance on a mathematics aptitude test administered at the beginning of the semester. Along with other influences, they reported mathematics ability as the basic effect of performance in physics class. It was suggested that low success rates in physics courses are largely because of a lack of mathematical skills and abilities. When given preference, students tended to choose conceptual or word problems because they did not contain any mathematical statements and complex formulas (Lonning and DeFranco, 1997). Therefore, taking into consideration the effect of mathematical skills and abilities on success in science courses, integration may be used in PBL scenarios.

Integrated teaching is defined and used in different forms, such as 'mathematics focused science,' 'mathematics and science focus,' and 'science focused mathematics' (Huntley, 1998). Another similar model was suggested by Roebuck and Warden (1998). Modifying Brown and Wall's (1976) continuum they proposed a continuum of math for math's sake, science-driven math, math and science in concert, math-driven science, and science for science's sake. To show the roles of the disciplines in synergy, this continuum was modified as MATHEMATICS – Science (**Ms**), MATHEMATICS – SCIENCE (**MS**), and SCIENCE – Mathematics (**Sm**) and sample lesson plans integrating physics and mathematics were prepared by Sahin and Berlin (2003) (see Figure 1). In the first category of the continuum, teachers teach only mathematics and use physics as the context and application of mathematical ideas, principles, and skills. It is designated with capital letter **M** and small letter **s** (**Ms**) to emphasize that only mathematics is taught. In the second category, teachers focus on both mathematics and science concepts and teach the two subjects jointly. This category is the one regarded as true integration since both subjects are taught and used as context for the other to reinforce the teaching of the other. It is designated with capital letter M and S (**MS**) to indicate that both concepts are taught in such a class. Only science concepts are taught in the third category of the continuum. Mathematics is used as the context to teach and apply the scientific principles, theories, and laws. It is represented with capital S and small m (**Sm**) to emphasize the science focus in this type of integration.

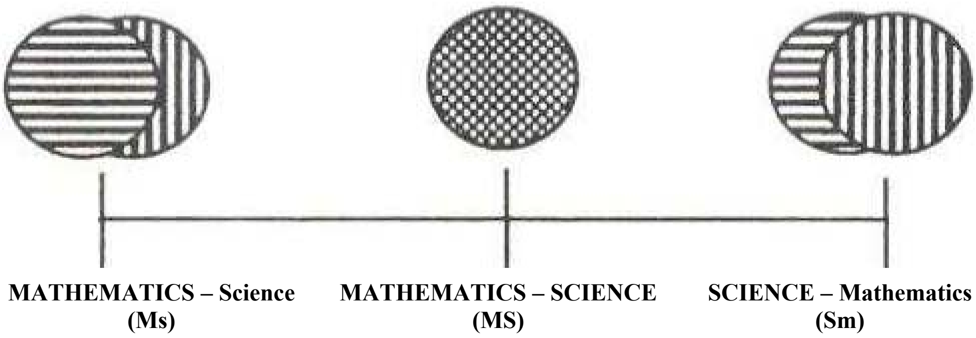

Figure 1. A Continuum Model for Science and Mathematics Integration. (Sahin and Berlin, 2003). Graphic (Huntley, 1998).

The same conceptual meanings can be used to teach different concepts in physics and mathematics. For instance, a straight line equation is in the form of $y = mx + b$ in mathematics and the relationship for the velocity of a particle moving with constant acceleration is given as $v_s = v_i + at$, where v_s is the final, v_i is the initial velocity, and a is the acceleration of the particle. These two equations are the same with different representations. Students in an integrated class will have the advantage of recognizing these two relations and realize that velocity – time graph of such a particle will be a straight line or the slope of the velocity – time graph of the particle will give its acceleration. It is important to note that synergy may enhance students' success in both disciplines and improve the chance for more discussion. An integrated scenario in a PBL class provides a context for exemplifying and helps students develop meaningful understanding in both disciplines.

It should be noted that synergy is possible for all disciplines which have similar topics and concepts. The extent where the subjects can be integrated, however, depends on the concepts and instructors.

(c) The Role of Instructors in Active Learning

The role and effect of instructors or facilitators are important for active learning processes to be efficient. Active learning programs may need facilitators, program designers and developers, and evaluation and measurement experts. Institutes using active learning techniques are advised to have enough personnel and encourage them to work collectively at every stage of the program to effectively conduct the process.

Since the planning and application of active learning may take extra time, instructors may have to spend more time on possible projects and working groups outside classrooms. Instructors may want to ensure that students understood the important points of the subject and most topics are touched upon. Teachers sometimes may have to make decision between students' learning and completing the curriculum. PBL personnel are devoid of any external rewards. A professor may gain more prizes from his/her research and publications (Bridges, 1992).

Facilitators, who are used to lectures and discussion classrooms, may become impatient in holding knowledge from students working and discussing in PBL classes. Instructors or TAs may need training in becoming a facilitator; otherwise, they may be unsuccessful in managing PBL groups. Furthermore, research indicates that some instructors may not perceive group work as a real teaching method (Bridges, 1992).

Apart from scenarios, the most crucial element affecting the success of a PBL program is the facilitator's guiding skills, knowledge, and abilities (Jones, 2006). Facilitation is so significant in PBL that the instructors in PBL often referred to as "facilitator." In this regard, a facilitator guides the students by asking leading questions, observes and motivates them by stating issues or realities about the problem. Facilitator skills include competences such as facilitation of small PBL group learning, an understanding of overall PBL process so that motivating students toward the objectives of the program, establishing an effective communication with students, and creating a warm, open, and safe atmosphere (Jones, 2006; Schmidt & Moust, 1995).

There is considerable debate about the significance of the facilitator being an expert in the content area. It is argued that an expert facilitator may provide students with the answers or alter the class toward a traditional lecture. However, a facilitator who is not an expert will only rely upon his/her facilitator abilities in facilitating the group discussion and may just see students develop their own solutions (Davis et al, 1992; Schmidt, 1994). Although there is debate about a facilitator's content area expertise, there is agreement among PBL specialist on the necessity for the training of facilitators for the success of a PBL program (Jones, 2006). To provide guidance to students and apply the PBL process with its principles, the best facilitator is probably the one who is familiar with the curriculum being taught, and trained properly in facilitation (Davis et al., 1992; Irby, 1996).

The essential factor motivating PBL faculty is the opportunity to motivate students by allowing them to participate actively in the learning process (Jones, 2006). However, being a good facilitator or designer is very different than wanting to be a facilitator of active learning. Planning, developing, and applying group work require time. Applications initiated by some individual efforts may be taken to a professional level by working collectively with other faculty so that the success of the PBL program could be attainable.

(d) Factors That Can Increase the Efficiency in PBL Approach

In this study, the topics that were thought to enhance the efficiency of PBL applications were elucidated and exemplified. These factors (although implicitly are in use in PBL scenarios), most of the time are not emphasized enough to have any effect on PBL outcomes. PBL literature indicates that it has been widely applied throughout the world and has positive influences on learning and students. We may actually see and observe such positive effects by at least trying to use small learning groups; emphasizing the work and role of facilitators and using the synergy between courses or integrating related topics where possible at a reasonable level in a scenario. A graphical representation showing the collective effects of important factors that are part of PBL process is shown in Figure 2. There may be some other factors affecting the PBL process, however, it is thought that influences investigated in this study are the foremost important factors that can change the outcome of a PBL classroom.

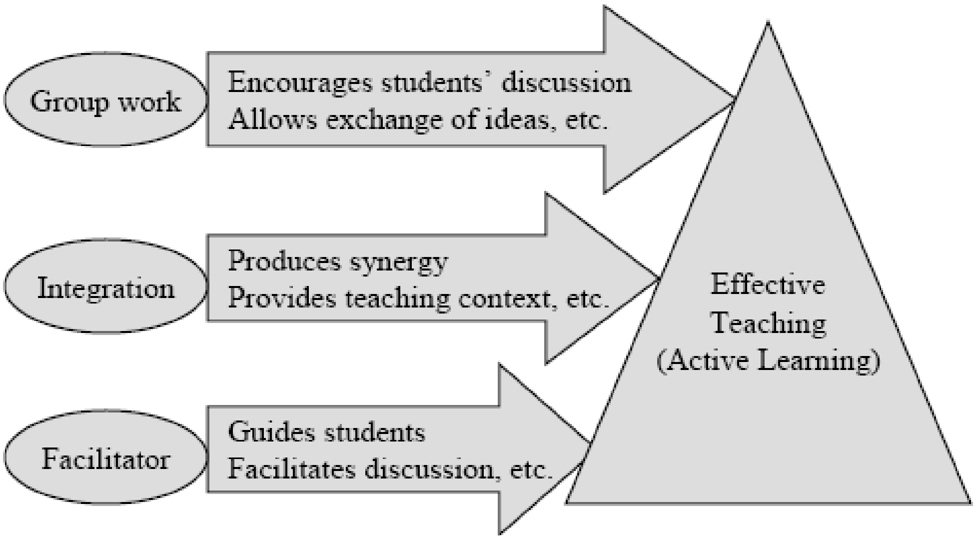

Figure 2. Factors That Can Increase the Efficiency in PBL Approach.

The main aims of active learning can be summarized as educating individuals who has critical thinking skills, high motivation, and high decision-making ability and who is an inquirer and researcher. To achieve these aims, it is important to evaluate and develop the program. Learning, which is defined and explored by some researchers as "meaningful memorization," "in-depth – shallow" approaches, and "active participation – passive reception," ensures direct incorporation of new knowledge to cognitive structure only if it is meaningful (Novak, 1998). Meaningful learning, according to Ausubel (1963, 1977), takes place by relating concepts in the course to student's prior knowledge. Thereby, the subject is learned as a whole and meaningfully (Woolfolk, 1998). It may be expected that any curriculum employing meaningful, in-depth approaches to learning and active participation may be more successful in enhancing and improving long-term understanding. Students need to have the ability for and appreciate the importance of lifelong and self-directed learning to be successful in their professions. As it was identified to develop students' knowledge and critical thinking and problem-solving abilities, PBL was regarded as a possible application to address these issues. PBL increases students' motivation to learn and provide self-directed learning opportunities for them.

SUGGESTIONS

This study dealt with active learning methods that place students at the core of the learning process. These approaches, when applied, mean a radical alteration in the teaching-learning curriculum of those countries whose education system relies heavily on traditional lecture, as in the case of Turkey. Therefore, the purpose of this paper was both to expedite the application and improve the efficiency of PBL by determining how to apply the method more efficiently in classrooms and improve students' success. For the purpose of this paper, a through literature review was carried out about integration, cooperative learning, active learning, and PBL and, as a result, some factors that are important for increasing the efficiency of PBL were determined.

Results of this review suggest that small group studies on scenarios may increase students' success in solving real-life problems. Students in small groups will increase within-group cooperation and each will develop a sense of self-confidence in speaking aloud. Solving problems within small groups rather than as a whole class may also help students learn better.

In addition, literature on integration, which is a very broad concept, implies that integrating science and mathematics may help students learn both subjects more meaningfully and the knowledge learned in this process tends to be long lasting. Scenarios used in PBL classrooms usually contain problems integrating more than one discipline (i.e., physics, mathematics, computer science courses, chemistry and/or materials).

Finally, it was indicated in the literature that facilitators might have a direct effect on the success or application of PBL process (Davis et al., 1992; Schmidt & Moust, 1995). When compared to traditional lecturing, instructor duties are completely different in PBL. Instructors, also called facilitators, are required to answer students' questions about problems, guide them by asking leading questions, and assume the role of a guide in the group. They do not introduce a direct proposition towards the solution of the problem. Facilitators are an important part of PBL approach. They should have the necessary skills and abilities about group management in PBL approach, and want to work in PBL applications. In order for PBL applications to be successful, it is important that facilitators should be listened to, and they should be informed regarding the expectations from them. Furthermore, they should be provided with the resources such as time, funds, feedback and motivation to ensure their ambitious work with students, which in turn may increase students' success.

Although there are a few places in Turkey where PBL is used, the education system relies mostly on traditional lecturing. Traditional lectures treat students as passive receivers and produce individuals who are accustomed to learning by rote and memorizing unnecessary details. Traditional education emphasizes teacher-centered education rather than educating students so that they can learn by themselves, have critical thinking, reasoning, and problem solving skills, know how to reach and obtain knowledge, and apply all the skills they learned to new problems and situations (Kalem & Fer, 2003). Article 16 in the Turkish Ministry of National Education (MNE) Principles of Teaching and Learning (MEB, 1998) states that students should learn by doing rather than seeing and hearing; and learning will be meaningful and permanent to the extent that students actively participate in the planning and application of lesson plans. PBL combines the real life and classes and helps students gain the skills to solve real life problems and learn how to learn. In this regard, the basic aim of PBL according to Cambourne (1998) is to prepare students to transfer school knowledge to real life. It is hoped that PBL approach will help students gain life long learning skills (Albanese & Mitchell, 1993; Allen, Duch & Groh, 1996).

In light of these results, it is advisable that research be conducted to evaluate the relative effects of group work, integration, and the role of facilitator in PBL approach, among others. Institutions using, or considering using, PBL approach should investigate the effects of these factors, and others, to gain the most out of PBL.

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