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Effects of Problem-Based Learning on Academic Achievement: A Meta-Analysis Study *

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Abstract

Today there is need for individuals who solve problems, who argue, question, change and take the lead and who use information instead of accumulating it. This need reveals the value of problem-based learning approach (PBL) which provides students to work in groups on a scenario prepared for the particular topic. Independent studies, aiming to determine PBL's impact on achievement when compared to traditional teaching, often focus on a particular type of application or operation. In the relevant literature, there are many studies on different educational fields, different lectures and different student groups concerning PBL's effects on achievement when compared to traditional teaching. This has lead to the need for meta-analysis of these studies. Therefore, this study aims to combine findings of independent studies through meta-analysis method. This integration is expected to contribute literature.

In the study, studies, which can be meta-analysed with regard to predefined criteria, were examined and 98 studies fulfilling these criteria were identified. Effect size and combined effects sizes were calculated with the help of the Comprehensive Meta Analysis v2.0 (CMA) Statistical Packet program.

The results of the study are the following: (1) The average effect sizes of studies included in meta-analysis done in line with random effects model is calculated as 0.83. This finding showed that according to traditional teaching, PBL's effects on academic achievement are high. (2) According to the analyses done in order to reveal publication bias, it was found that meta-analysis study has no publication bias. (3) It was found that PBL approach affects the studies teachers and master's students the most and affects faculty members studies the least. (4) It was found that sample

Keywords

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size of the PBL's groups, big or small, has no significant impact on student achievement. (5) It was identified that PBL's effects on student achievement when compared to traditional teaching has not changed according to field of sciences PBL was applied. (6) There is no difference between the academic achievements of different educational levels where PBL was applied. (7) PBL's effects on academic achievement, does not depend on the approach's application time in the teaching-learning process. In addition to its research findings, this study includes descriptive analysis results of studies that were included in meta-analysis

Introduction

In the 21th century, several developed and developing countries question their traditional education philosophies and education programs that are consolidated by these philosophies, where the lecturer is the transmitter and the student is the receiver, for the education of thinking, problem solving, evaluator, decision maker, responsible, creative, up-to-date individuals who fit this age of information and technology. In the traditional understanding, education program, content of a lecture's subject area, education plan and quantitatively calculated education output are considered as studies in terms of reproduction of culture and preservation of the current social order (Tanner and Tanner, 2007). The major goal of education is to preserve the best in the past and to handle new subjects in the same manner. In addition, it is argued that traditional education philosophies are considered the best for improving knowledge whose power is the only way to deal with contemporary problems (Tanner and Tanner, 2007).

Traditional education is criticised for the following reasons: In essence, it is externally enforced; it is the imposition of adults' standards and subjects to the young by force; its subjects are exceeding the current capacities of young students; it pays no attention to student life; it blocks student participation and it defines student's task as considering school books and adults' teachings (Dewey, 1997). This discontent towards traditional education leads to the rise of progressive education philosophy. According to Dewey (1997), features of progressive education philosophy are:

- The consciousness of being an individual should be developed instead of coercive education.
- Students' freedom of action should be recognised instead of externally enforced discipline.
- Education should be through life experiences instead of through lecture books and teachers.
- Particular skills and techniques should not be learned from exercises but they are to be considered as tools in life in order to reach goals.
- Students should take a good advantage of today's opportunities instead of preparing for distant future.
- Students should get to know the changing world against stable aims.
- A close relationship should be established between real life and education processes.

As features of progressive education indicate, progressive education underlines education of students through real life experiences without being isolated from social environment and society. In progressive education, issues encountered in current life are considered as problems. Therefore, new ideas bring new problems forward and provide a basis for the formation future experiences. Thus, according to the supporters of pragmatism approach-based progressive education, problem solving method in teaching should be essential. Students should learn to think, do research and reach the solution on their own. Students should be gained capacities of problem solving; critical thinking and

doing scientific research and educational experiences provided should be based on cooperation (Ornstein and Hunkins, 2004).

According to Gagne (1959), the main purpose of an education program is to teach students to solve problems concerning both subjects and their life-time experiences. This is necessary because problem solving ability helps an individual to adapt the environment actively; it is also prerequisite for individual to become questioning and problem solving individuals (Marzano, 1989). Therefore, individuals having these qualifications should have high level thinking skills. Thinking begins with a problem and problem solving directs an individual's thinking (Kalaycı, 2001). According to Gagne (1985), problem solving triggers the most complicated cognitive processes and enables simultaneous use of several important skills including learning by trying, establishing cause-effect relationship and assessment of the relations between concepts and events.

Traditional programs that depend on transferring ready information from books or teachers should be replaced with programs that rely on learning by problem solving and consider knowledge as an instrument only (Ertürk, 1979). In this point as Dewey suggested, progressive approaches which encourages students to do research, discover and use their creativity, have become important; problem-based learning (PBL) is one of these approaches (Delisle, 1997). Thus, PBL's value has been revealed through the current need for problem solving, discussing, questioning, changing, leading individuals who use knowledge rather than accumulating it. PBL is highly effective in developing all these skills of individuals (Tatar and Oktay, 2011; Peterson and Treagust, 1998). Results of several studies indicate PBL's effects on developing these skills (Kılınç, 2007; Açıkyıldız, 2004; Harland, 2003; Mayer, 2002).

PBE, through scenarios that can be encountered in real life, directs students to do research, learn, discuss, choose the best option among many solutions, using these in application; briefly it is an approach which teaches students research, team work and observation from multi-perspectives (Deveci, 2002; Kaptan and Korkmaz, 2002). PBL assumes that learning emerges in a problem oriented media and it is a product of cognitive and social interaction. According to this assumption, PBL is defined as a constructivist education model which includes teaching of general principles that are used in solving similar problems and knowledge that is used for solving future problems (Norman and Schmidt, 2000; Greeno, Collins and Resnick, 1996).

PBL was first developed in the 1960's in United States of America in medicine faculty programs. It was developed to replace lecture based problems with programs depending on real life experiences; in a way it was applied as an alternative for traditional education to increase student achievement (Savery and Duffy, 1995). After it was applied in medicine, PBL has been applied to different fields in the world such as social sciences, natural sciences, computing, mathematics, art, nursery, engineering, dentistry, law, and architecture (Loyens, Magda and Rikers, 2008; Newman, 2003; Kenn, 1996). As a result of successful applications, effects of the approach on student achievement in primary, elementary, high school and college education were showed in many studies (Sungur and Tekkaya, 2006; Lawrance, 2006; Murray and Savin-Baden, 2000; Gallagher, Stepien and Rosenthal, 1992; Duch, 1996).

In the literature, experimental studies done in different scientific fields, different lectures and different student groups, there are many studies indicating the effects of PBL on student achievement. This causes the need for meta-analysis. Comprehensive and credible high-level studies are needed in order to interpret similar studies' knowledge accumulation and to raise new studies (Akgöz, Ercan and Kan, 2004). These studies done in the same subject were not interpreted as a whole, it is a deficiency. On the other hand, in order to emphasize PBL's significance for education systems, an independent experimental study might contribute to the literature. However, independent studies mostly focus on a single application type or an experiment. These studies on their own cannot provide comprehensive information concerning the subject (Cook, Cooper, Cordray, Hartmann, Hedges, Light, Louis and Mosteller, 1992). Science is considered as gathering and classification of knowledge; it deals with mostly generalisations that predict future events, rather than single events (Radin and Ferrari, 1991; Wolf, 1986). Particularly in social science, it is considered that a single study does provide precise answers for such generalisation (Glass, 1976). The meta-analysis method however, shows that generalisations can be achieved through integration of similar studies' findings (Hunter and Schmidt, 2004). In summary, through meta-analysis, it is aimed to reach a more precise decision about a subject and making more clear assumptions and generalisations about the future. Therefore this study is considered to contain all previous independent studies and consequently it will contribute the literature in a more affective way. In addition, different from the scholars who think that PBL affects achievement and performance (Phan, 2008; Eom, Wen and Ashill, 2006); some researchers argue that PBL has no effects or a low-level effect on achievement (Dobbs, 2008; Dehkordi and Heydarmejad, 2008; Reeves and Loffey, 2006; Hansemark, 1998; Albanese and Mitchell, 1993). In this matter, PBL is criticised that in the PBL process, students who lead their own learning, do not learn totally while they try to collect information (Liu, 2004; Savery and Duffy, 1995). Therefore, in order to determine PBL's effects on student achievement, different findings were found in these two extremes. This situation indicates that single study on a research topic is not enough or it does not give credible information and shows the importance of meta-analysis studies.

Meta-analysis is a statistical method that combines the results of similar studies in a coherent and consistent way (Cohen, Manion and Morrison, 2011). In the literature, there are many studies that are based upon PBL and meta-analysis (Üstün, 2012; Walker and Leary, 2009; Gijbels, Dochy, Van den Bossche and Segers, 2005; Colliver, 2000). Nevertheless the studies conducted by foreign researchers were done mostly in the health field. Also they often include only a few studies in Turkish or totally neglects studies done in Turkey. Therefore, this study is different from these above-mentioned studies. For example, Dochy, Segers, Van den Bossche and Gijbels (2003), in their study aiming to do meta-analysis for experimental studies in the field of medicine, focus on PBL's effects on students' knowledge and skills. According to the results of the study, PBL has considerably positive effects on medical students, particularly in terms of skills such as acquiring knowledge and using it. Leary (2012) also did a study and investigated the effects of self-regulating learning strategies on student performance. In the PBL process, only self-regulating learning strategies were included in meta-analysis; thus, the study seems to deviate from the aim. In another study, Walker and Leary (2009) did a meta-analysis study. They examined 82 studies in terms of application types, problem types, discipline fields and assessment types of the PBL approach. This study is different from the studies that were done with regard to independent variables. In addition, the studies conducted by domestic researchers were examined, it was also determined that they were different from the present study (Batdı, 2014; Üstün, 2012). In Üstün's (2012) doctoral thesis, it was investigated the effectiveness of PBL on student achievement, motivation, attitudes and skills in science. So, 52 studies were included in the meta-analysis to specify the effectiveness of PBL on achievement. This study also varies from the present study in terms of coverage the only studies conducted in the field of science. In Batdı's (2014) study, only 26 studies which were conducted to compare PBL with traditional teaching in terms of academic achievement between the years 2006-2013. However, the meta-analysis conducted in the study was not involved all the independent studies about this issue in the literature because of the

year limitation. Therefore, when the all meta-analysis studies have been analysed, the originality of the present study is observed.

While the findings of previous meta-analysis studies are examined, it is found that PBL is mostly effective on developing skills such as problem solving, remembering information, doing research however it has no or minimum effect in terms of increasing student achievement (Albanese and Mitchell, 1993). However, some studies are stated that PBL approach is more effective than traditional teaching (Üstün, 2012). Therefore it is important to do a recent meta-analysis study in order to re-examine PBL's effects on academic achievement. In addition, in the literature there is no meta-analysis study which involved the researches made in all field of science and included the findings of researches made in Turkey. So, this study is expected to contribute to the literature in terms of generating scientific proof with regard to PBL's effects on achievement. The study combined the findings of studies on different places and time and different student groups. In doing so, the study aimed to reach a more explicit conclusion concerning PBL's effects on academic achievement.

Consequently, the purpose of this study is to reveal PBL's effects on students' academic achievement when compared to traditional teaching. In this context, the research question of this study is the following: Do the research findings concerning PBL's effects on student achievement as compared to traditional teaching, have significant differences in support of PBL while effect sizes are considered? Besides, the sub-questions of the study are:

1. What is the distribution of studies that were included in meta-analysis according to the independent variables?
2. What kind of effect does PBL have on academic achievement when compared to traditional teaching?
3. Is there a significant difference between effect sizes of published and unpublished studies in the literature?
4. Is there a significant difference between effect sizes of the studies according to the PBL's executor?
5. Is there a significant difference between size effects of the studies according to sample sizes?
6. Is there a significant difference between effect sizes of the studies with regard to the scientific field where PBL was applied?
7. Is there a significant difference between effect sizes of the studies according to the education levels of the students where PBL was applied?
8. Is there a significant difference between effect sizes of the studies with regard to the PBL's application time?

Method

In the study, meta-analysis was adapted as a method. Meta-analysis is an analysis method aiming to combine statistical analysis of the qualitative finding of the independent and similar studies and results of the studies in a coherent and consistent way (Cohen, 1988). The findings of the studies were converted into the common measurement unit, called effect size. Effect size is considered as the basis of meta-analysis. It constituted the dependent variable of this meta-analysis study.

The Concept of Effect Size

Size effect is the main unit of meta-analysis studies. This concept is used in order to determine the relationship between two variables or the size of application effect (Borenstein, Hedges, Higgins and Rothstein, 2013). In the meta-analysis studies, size effect index varies according to the type of meta-analysis. Durlak (1995) defines two type of meta-analysis: group contrast meta-analysis and correlation association meta-analysis.

In group contrast meta-analysis, standardised effect size is calculated to show mean difference between groups. In order to determine the difference between the groups, standardised effect size is used. The concept is shown "d" or "g". This value is calculated through division of the difference between two groups' means by dividing it to total standard deviation (Durlak, 1995). If these two above-mentioned groups were created by the researcher as experiment and control groups, comparative meta-analysis done between these two groups is called treatment effectiveness meta-analysis; if the group is naturally emerged (such as male and female); it is called group difference meta-analysis (Durlak, 1995). In this way, it is aimed to combine data of independent studies in a single value and to compare their effect sizes.

The second type, correlation association meta-analysis focuses on the relation between variables of the studies, which are included in meta-analysis. Product-moment correlation is used as a statistical indicator (Glass, 1976). In order to generate comparable results that can be used in the meta-analysis, the correlation between two variables are examined. This correlation association meta analysis is called test validity meta-analysis; if there are more than two variables' covariance are focused, it is called variable covariancetion meta-analysis (Durlak, 1995).

While the interpretation of calculated size effect is considered, according to Cohen the study's effect size value:

- is 0.20 and less, there is a low-level effect
- is between 0.20 and 0.80 there is a medium-level effect;
- is 0.80 and over, there is high-level effect (Cohen, 1988).

Types of Meta-Analysis Model

After calculation of meta-analysed studies' size effect, these values are combined in accordance with the convenient meta-analysis model. In meta-analysis studies, two meta-analysis models are commonly used: fixed effects model and random effects model.

Fixed effects model is based on the assumption that, all meta-analysed studies' real effect sizes are shared and factors that can chance effect size are same in all studies (Borenstein et. al., 2013). Real effect size is the effect size that is acquired from the sample or very large sample groups. In the fixed effects model, real effect size of all studies is assumed same, in other words homogenous (Field, 2001). However, this assumption is impossible, especially when similar independent studies' findings are desired to be integrated. Therefore, this situation necessitates random effects model. In the random effects model, real effect size of all studies is assumed different, in other words heterogeneous (Field, 2001). The studies are not expected to be homogenous while it is aimed to combine independent studies with similar findings. For instance, when a study examines the effects of a method application on students' affective skills, the studies', whose findings are to be combines, effect sizes are expected similar but not same. Because the executed group or factors like executor's age, education level or gender are different, each study's effect size is probably different (Üstün and Eryılmaz, 2014). This difference between studies can be shown through a meta-analysis study depending on random effects model.

Data Collection

This study includes convenient master's and doctorate theses completed in Turkey and abroad, manuscripts published in journals, electronically formatted articles and proceedings gathered from international databases. In order to reach these sources, firstly High Education Board's thesis catalogue was scanned. Besides, the researcher visited university libraries or contacted writes of theses, whenever the documents were not reached online.

The researched scanned electronic catalogues (through remote access or personal visits) of the libraries of the following universities: Hacettepe University, Middle East Technical University, Ankara University, Boğaziçi University, Karamanoğlu Mehmetbey University, Anadolu University, University of Boston, University of Clemson and Moscow State University. Among the reference indexes and databases, Science Citation Index, Social Science Citation Index, Arts and Humanities Citation Index, ERIC (Educational Resources Information Center), Proquest Digital Dissertations were scanned. In addition, the study benefited from Google Scholar search engine. The author sent e-mails to the researches in order to access whole manuscripts. Some studies, whose authors were not reached, were purchased through ULAKBİM National Combined Catalogue service.

During electronic scans, expressions such as "problem-based learning", "traditional teaching", "meta-analysis" "the effects of problem-based learning on achievement" and their equivalents in English were written both in and without quotation. The bibliographies of the sources were also examined and through this method, new sources were accessed.

Aftermath a comprehensive literature review, 141 studies that are in accordance with this study's aim, were found. However the studies that do not meet the meta-analysis criteria were eliminated. The meta-analysis criteria of this study are: the scope of studies whose findings were used and studies which have necessary statistical data for analysis (Wilson, Lipsey and Derzon, 2003). Studies that were included in meta-analysis have these following criteria:

1. The aim of the study is to find PBL's effects on student achievement when compared to traditional teaching.
2. The study which includes an experimental design with control group were included in the meta-analysis. Traditional teaching in the control group and PBL in the experimental group were applied. In these studies, traditional teaching is defined as a teacher centered approach based on lecturing and textbooks.
3. The study includes necessary statistical information to calculate effect size of the research. These statistics are analysis results of t-test and "F" test or sample size, mean and standard deviation values of the groups.

Studies that are not compatible with the scope of the research and studies that lack necessary statistical data were excluded. Consequently in this study, studies which are compatible with the predefined criteria were examined and included in the meta-analysis. Finally, 98 studies which meet these criteria were identified.

Steps of Meta-Analysis in the Study

In this study, this process was followed in line with the meta-analysis method application steps:

- First of all, in the literature studies analysing PBL were examined in order to determine the research question and dependent and independent variables were chosen. Then, in line with the dependent and mediator variables, the research question of the study and sub-questions were determined.
- After the finalisation of the research question, a compressive literature review was launched and sufficient sources were accessed for meta-analysis.
- After literature review, studies that meet criteria for meta-analysis were analysed and the mediators of the study were identified. These studies were coded through a coding form that was developed by the researcher.
- In order to calculate effect size index of the included studies, treatment effectiveness meta-analysis method was used as a meta-analysis type. In order to calculate effect size of these studies, frequency, standard deviation and arithmetic mean values or values derived from test statistics of the research findings were used.

- In order to combine effect sizes of the studies, random effects model, which is used when studies are heterogeneous, was applied. Analyses were made with the help of CMA program.
- In the final stage of the study, research findings obtained after the method was applied, were interpreted and turned into a report.

Validity and Credibility Study on Coding Process

Coding form was using during the coding process of meta-analysis. Coding form was used to convert information to numerical data via coding. In the coding process, primarily the coding forms of the meta-analysis studies done, previously have been examined (Rudy, 2001; Bayraktar, 2002; Ergene, 1999). In the selection process of the mediators, the studies about the effectiveness of PBL were examined and the factors that affect the PBL approach were listed from these studies (Leary, 2012; Walker and Leary, 2009; Kaufman and Mann, 1999). The purpose of the study was explained to three academics, who work on educational sciences and PBL and who want to join meta-analysis process. They were informed about meta-analysis method and coding process. Before coding form was developed, two similar studies were selected. These studies were examined together with coders. Coding form was developed with the help of the sample coding form (Ergene, 1999) and discussion with each researcher. It was formed in accordance with the predefined independent variables of meta-analysis study. In addition, experts were consulted in order to secure content validity of the form. According to the expert opinion, the item of the status of the researchers (who made the PBL application in experiment groups, the researcher of the study or another educator?) was added to the coding form.

After coding form was developed, the researcher developed an additional form which includes the explanation about coding form. This explanatory form was tested on an article by the coding team. Unclear parts of the explanatory form were corrected. Then, 10 studies that were included in meta-analysis were randomly selected and e-mailed to the researchers. The researchers were asked to do coding in a particular duration. During this time, the author also did coding with the help of Microsoft Excel software.

In meta-analysis studies, a criterion for the coder and inter-coders credibility can be used; this is called "agreement rate" and it is acquired by dividing accepted viewpoints to the total viewpoints (Orwin and Vevea, 2009; quoted in Üstün and Eryılmaz, 2014). In addition, Krippendorff's Alpha, Cohen's Kappa or interclass correlation, which measures coding similarities between two or more coders, can be used in meta-analysis studies in order to determine the credibility of the form (Leary, 2012). In the study, in order to determine the credibility of coding process, credibility was tested between coders with the help of coded findings of 10 studies. Credibility coefficient of the study was found .92. This value indicates that coding process is credible (Ergene, 1999). Consequently, the coding form of the study includes publication year and publication status and type of the studies, executor, education level of the group, application time, subject field of the application and other mediator variables concerning the studies that were included in the meta-analysis.

Data Analysis

In this study, meta-analysed each study's effect size values and combined effect size were calculated with the assistance of Comprehensive Meta-Analysis Software v2.0.

The CMA software calculates effect size by using reported findings of the studies that were included in meta-analysis. However, as each study is independent, reported findings can be in different formats. For example, some studies report only significant differences and sample size while some studies additionally report means and standard deviation. In this case, in order to combine each study under a common value, the CMA software facilitates to calculate effect size after selecting different format types and the most convenient data input (Borenstein, Hedges, Higgins and Rothstein, 2004). In calculating effect sizes (Hedges' g), this study selected formats which are suitable for experiment and control groups' means, standard deviation values, sample sizes or test statistics. In

order to determine whether each study tests the same hypothesis or not, heterogeneity test was done with the help of the CMA software. According to the heterogeneity test, effect sizes of studies are statistically significant. In other words, values were distributed heterogeneously. Thus, effect sizes were calculated through random effects model in this study.

In analysing data, treatment effectiveness meta-analysis was employed as a method. This method used mean differences between experiment and control groups of the studies that were included in meta-analysis, number of samples in studies, arithmetic mean, standard deviation or test statistics (F, t, X^2 etc.) of the groups and identified effect sizes that were calculated in "Hedges g" value (Durlak, 1995). Besides, in analysing descriptive data, the study benefited from the SPSS 15.0 statistical software. Significance level of the statistical analysis was selected as .05. Data input of the coding form was done through de Microsoft Excel 2007 software.

Results

This chapter includes research findings according to the sub-questions.

Research Findings Concerning the First Sub-Question of the Study

The first sub-question of the study is the following: "What is the distribution of studies that were included in meta-analysis according to the independent variables? In line with this selected question, Table 1 shows publication years and distribution of the studies that were included in meta-analysis.

Table 1. Distribution of the Studies According to Their Publication Years

Year of Publication	Number of Publication	Year of Publication	Number of Publication
1997	1	2008	8
1998	1	2009	14
1999	2	2010	15
2002	2	2011	13
2003	3	2012	9
2005	3	2013	7
2006	8	2014	2
2007	10		
Toplam	30	Total	68

As seen on Table 1, publication years of the meta-analysed studies vary between 1997 and 2014. In addition, it is observed that studies that analyse according to traditional teaching, PBL's effects on academic achievement have become common after the year 2005. Most studies were done in 2009 (14 studies), 2010 (15 studies) and 2011 (13 studies).

This study used mediator variables in order to determine similar and different features of studies that were included in meta-analysis. Mediator variables were considered as publication status of the study, type of the study, the executor and his or her status, sample size, science field of the application and application duration (hours). The results of descriptive analysis of these categorical independent variables are given on Table 2 as frequencies and percentages.

Table 2. The Descriptive Analysis of the Independent Variables

Mediator Variables	**Frequency**	**Percent**
Work Publication Status		
Published	51	%52.04
Unpublished	47	%47.96
Total	98	%100.00
Type of Study		
Article	51	%52.04
Master's thesis	31	%31.63
Doctoral thesis	16	%16.33
Total	98	%100.00
The Person Who Conducted the Studies/PBL's executors		
Teacher	38	%38.80
Master's student	19	%19.40
Doctoral student	11	%11.20
Faculty staff	30	%30.60
Total	98	%100.00
The Status of the Researcher Who Conducted the Studies		
Researcher himself/herself	40	%40.80
Not a researcher of a study	53	%54.10
Unspecified	5	%5.10
Total	98	%100.00
Sample Size / Person		
1-20	18	%18.40
21-30	26	%26.50
31-50	29	%29.60
51 and more	25	%25.50
Total	98	%100.00
The Field of Science		
Sciences	58	%59.20
Mathematics	15	%14.30
Social Sciences	14	%15.30
Health Sciences	8	%8.20
Computer Sciences	3	%3.00
Total	98	%100.00
The Students' Education Level		
Primary	4	%4.10
Secondary	26	%26.50
High school	23	%23.50
Undergraduate	45	%45.90
Total	98	%100.00
The Time Taken for the Studies / Hour		
1-16	34	%34.70
17-48	37	%37.80
49 and more	22	%22.40
Unspecified	5	%5.10
Total	98	%100.00

As seen on Table 2, meta-analysed studies include 51 peer-reviewed articles, and 47 unpublished studies; they are 31 master's and 16 doctoral thesis. It was observed that in experiment groups, PBL applications were mostly executed by teachers (n=38) and faculty staff (n=30). Teachers were accepted as employees who are responsible to give lectures on education levels except high education; faculty staff contains faculty members, instructors, lecturer and teaching assistants that were employed in high education institutes. In addition, when the findings concerning the executors (whether the researchers or class teachers), the application was executed mostly by class teachers (%54.10) than researchers himself/herself. The number of the study which is specified that the researcher is an official teacher of the class is 6. Because the number is low, these studies were counted among the applications conducted by researchers. When meta-analysed studies were examined, in many of them the executors were informed by the researcher about PBL or they had previous knowledge about the subject (Folashade and Akinbobola, 2009; Yurd, 2007; Uslu, 2006; Maxwell, Bellisimo and Mergendoller, 2001).

Sample size of experiment groups of meta-analysed studies were classified in accordance with the frequency distribution of studies. According to this classification, there are 18 studies done on 1-20 person samples, 26 studies done on 21-30 person sample, 29 studies done on 31-50 person sample and 25 studies whose sample size are over 51 persons. PBL applications were identified on the fields such as Sciences (n=58), Social Sciences (n=14), Mathematics (n=15), Computer Sciences (n=3) and Health Sciences (n=8). In Sciences, the data acquired from the findings of the studies concerning Physics, Chemistry, Biology and Science and Technology courses and their laboratory studies done in different education levels were included. In Social Sciences, data of the studies concerning Geography, History, English, courses of Educational Sciences, Life Sciences, Social Studies, Psychology and Economics were included. In the field of Health Sciences, medicine and nursery courses, in the field of Computer Sciences, Knowledge, Technology and Network courses, in Mathematics, Mathematics, Geometry and Algebra courses were included. It was observed that PBL applications were done mostly in graduate (n=45), secondary (n=26) and high school (n=23) levels. Only 4 studies were accessed in terms of primary school level. With regard to education levels, 1., 2., 3., 4. and 5. grades were accepted as primary school; 6., 7. and 8. grades were considered as elementary school and 9., 10, 11. and 12. grades were accepted as high school level. Applications made in the universities were evaluated as graduate level. Finally, PBL's application time was identified in experiment groups in hours. It was found that PBL's minimum duration was 3 hours, maximum duration was a whole semester. Frequency distribution, arithmetic mean and peak value of the studies were taken into consideration and application time was grouped. The groups are the following: 3-16 hours (n=34), 17-48 hours (n=37), over 49 hours (n=22). Also, the application time has not specified in 5 studies.

Research Findings Concerning the Second Sub-Question of the Study

In this study, in order to answer the question "What kind of effect does PBL have on academic achievement when compared to traditional teaching?", effect sizes of the studies that were included in meta-analysis were calculated. Table 3 indicates heterogeneous distribution value, average effect size and confidence interval of the studies in line with the effects model.

Table 3. Average Effect Size and Confidence Interval Upper and Lower Values According to Effects Model

Model	N	Hedges's g	95% Confidence Interval		Q-between classes effect	P
			Lower	Upper		
Fixed effects model	98	0.76	0.72	0.79	1922.21	0.00
Random effects model	98	0.83	0.66	1.00		

As seen on Table 3, acquired effect sizes vary between 0.79 (upper) and 0.72 (lower) of the 95% confidence interval according to the fixed effects model. Average effect size value (Hedges's g) was calculated 0.76. However, it was questioned whether this meta-analysis study fits to the fixed effects model or not. In doing so, heterogeneity test was applied. The result of this test ($Q=1922.21$; $p<.05$) indicates that distribution is not homogenous (is heterogeneous). Consequently the study adapted random effects model instead of fixed effects model. According to the random effects model, limit upper was found 1.00 and limit lower was found 0.66 of the 95% confidence interval. Average effect size value was calculated 0.83. As these findings were interpreted in the light of Cohen (1988)'s framework, it was found that PBL has high level effects in terms of increasing academic achievement when compared to traditional teaching.

Before interpreting PBL in accordance with the independent variables, in order to confirm this finding (PBL has high level effects (0.83) on academic achievement, Classic Fail-Safe N analysis were used in order to determine the power of meta-analysis study. The results of the analysis were given on Table 4.

Table 4. Classic Fail-Safe N

Power of the Meta-Analysis	
Z-value	37.14
p-value	0.00
Alpha value	0.05
Alpha value for the Z-value	1.95
N	98
p>the number of missing studies for the alpha result	5092

According to the Classic Fail-Safe N analysis given on Table 4, in fact that p value is smaller than value of alpha is an indicator of the powerful and reliable study. So, in order to invalidate results of meta-analysis, 5092 individual studies were needed ($p<.05$).

Another analysis showing the power of meta-analysis study is the analysis done whether there is a publication bias in meta-analysis study. For this purpose, publication status of the studies that were included in meta-analysis was among the mediator variables.

Research Findings Concerning the Third Sub-Question of the Study

In the study, the results of the analysis concerning the question "Is there a significant difference between effect sizes of published and unpublished studies in the literature" were given on Table 5.

Table 5. The Effect Size Differences According to Publication Status (Analysis Results of Publication Bias)

Model	**N**	**Hedges's g**	**95% Confidence Interval**		**Heterogeneity Test**	
Random Effects Model			**Lower**	**Upper**	**Q-value**	**P**
Unpublished	47	0.84	0.62	1.07		
Published	51	0.83	0.57	1.07		
Total Between*					0.01	0.87

* How accurate is the publication status variable in explaining total variance

As indicated on Table 5, the average effect size (Hedges's g) of the published studies was found 0.83 in accordance with the random effects model. This value was found 0.84 for unpublished studies. According to the result of heterogeneity test, there is no significant difference between effect sizes of published and unpublished studies concerning PBL's effects on academic achievement according to traditional teaching ($Q=0.01$; $p>.05$). In other words, among the selected studies, in the meta-analysis study done to determine PBL's effects when compared to traditional teaching on

achievement, effect size averages of published and unpublished studies are close to each other and they are homogenously distributed.

In this case, it can be said that meta-analysed studies do not have publication bias. The funnel graphic given on Figure 1 indicates this situation.

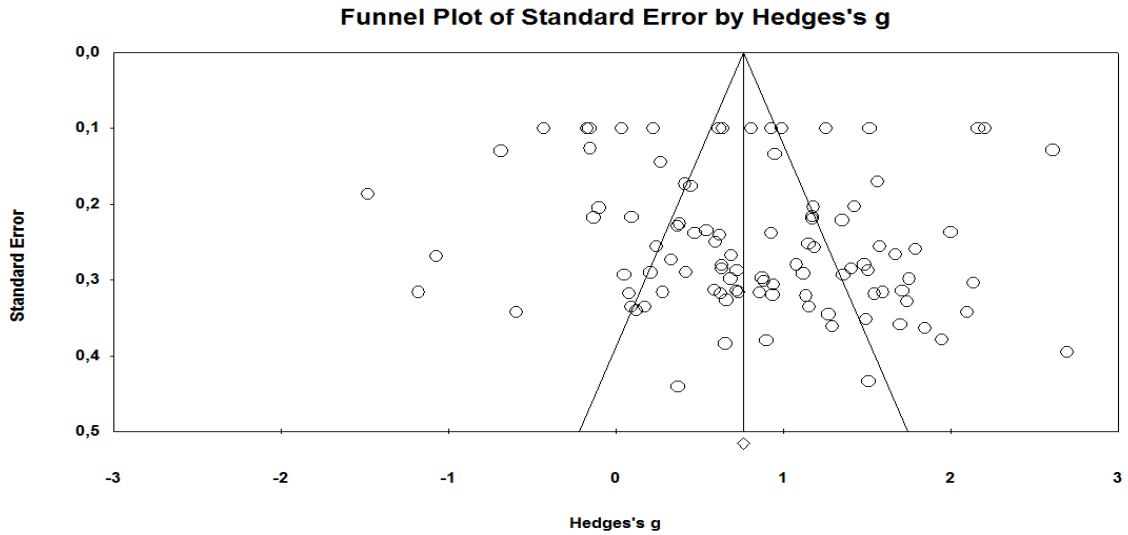

Figure 1. The Funnel Graphic

Figure 1 shows distribution of the studies that were included in meta-analysis. It is observed that studies do not present an asymmetrical distribution. In other words, distribution is not concentrated in a particular part. As there is no asymmetrical distribution, study's sample is not in support of PBL, because when there is publication bias, asymmetrical and skew distribution is expected on the graphic (Üstün and Eryılmaz, 2014).

As no statistical information was acquired from the graphic, Begg and Mazumdar's rank correlation test was employed. This test indicated that the study's sample is not biased. Results of the analysis that were obtained from the test were presented on Table 6.

Table 6. The Publication Bias Condition of the Studies

Publication Bias	
Kendall's S (P-Q)	536.00
Kendall's tau	0.11
Tau for z-value	1.64
P	0.09

According to Table 6, the suggestion that meta-analysed studies were not biased, was proved once more (tau=0.11, p>.05).

Research Findings Concerning the Fourth Sub-Question of the Study

The study also asked this question: "Is there a significant difference between effect sizes of the studies according to the PBL's executor?". The results of the analysis made to answer this question are presented on Table 7.

Table 7. Effect Size Differences According to the PBL's Executor

Model Random Effects Model	N	Hedges's g	95% Confidence Interval Lower	Upper	Heterogeneity Test Q-value	P
Teacher	38	1.00	0.70	1.30		
Master's student	19	1.08	0.76	1.41		
Doctoral student	11	0.85	0.35	1.34		
Faculty staff	30	0.46	0.21	0.71		
Total Between*					11.65	0.00

* How accurate is the PBL's executor variable in explaining total variance

As seen on Table 7, meta-analysed studies in accordance with random effects model, the following results were found in terms of PBL's executors: the average effect size of PBL on achievement (Hedges's g) is 1.00 for teachers; 1.08 for master's students; 0.85 for doctoral students and 0.46 for faculty staff. Heterogeneity test was employed in order to find out whether there is a significant difference between effect sizes of the studies in terms of PBL executors. Accordingly, there is a significant difference between average effect sizes of the studies in terms of academic achievement ($Q=11.65$; $p<.05$). Research findings indicated that PBL's effects on student achievement when compared to traditional teaching are the strongest in the applications that were executed by teachers and master's students. The least effect was found among the studies done by faculty staff. When size effect values are considered (Cohen, 1988), PBL's effects on achievement according to traditional teaching is high level in studies performed by teachers, doctoral and master's students whereas they are low level for faculty staff.

Effect size in faculty staff's studies was found low. When this difference between executors was considered, it was suggested to find out what sort of factors played a role for this finding. For this purpose, it was considered important to determine whether faculty staff is different from other executors in terms of whether executor is a researcher or not, PBL application time and sample sizes. It is aimed to interpret differences in achievement levels which might stem from different executors of PBL. First of all, descriptive data concerning the executor of PBL (whether he or she is a researcher or not) were given on Table 7a.

Table 7a. The Descriptive Data Concerning the Executor of PBL

The Status of the Researcher	Academic Researcher		Not Researcher	
	Frequency	Percent	Frequency	Percent
Master's student	110	52.10%	8	41.10%
Doctoral student	7	63.60%	4	36.40%
Teacher	14	36.80%	22	57.90%
Faculty staff	9	30.00%	19	63.30%
Total	40		53	

Table 7a presents meta-analysed studies' research findings concerning the executor of PBL. According to findings doctoral students (63.60%) and master's students (52.10%), in comparison with teachers (36.80%) and faculty staff (30.00%), are mostly execute application in experiment groups as researchers. In the studies included in the analysis, the number of the studies which were not specified who did PBL application is 5 and they were excluded from the frequency distribution in table 7a. In addition to the executors, determining application time is considered important for revealing the

reasons of differences which do not stem from executors. Therefore, Table 7b indicates frequency and percentage of application time according to PBL executors.

Table 7b. The Descriptive Analysis of the Application Time According to PBL Executors

The Time Taken for the Studies	1-16 (hour)		17-48(hour)		More than 48 (hour)	
	F	%	F	%	F	%
Master's student	9	47.40%	8	42.10%	2	10.50%
Doctoral student	2	18.20%	5	45.50%	4	36.40%
Teacher	14	36.80%	15	39.50%	4	10.50%
Faculty staff	9	30.00%	9	30.00%	12	40.00%
Total	37		52		20	

According to table 7b, for the all executors, mostly include applications that lasted 17-48 hours. However, it was observed that faculty staff did studies on applications that lasted more than 49 hours. On the other hand, durations of master's students' applications were shorter. Also, 5 studies (5.10%) did not report application duration; therefore frequency distribution of these studies was not included on table 7b. Another factor that might influence effect size values in PBL values was sample size of the application groups. On Table 7c, sample size of the application groups were compared according to the executors.

Table 7c. The Descriptive Analysis of Sample Size According to the Executors

Number of Students	1-20		21-30		31-50		More than 50	
	F	%	f	%	f	%	f	%
Master's student	3	15.80%	8	42.10%	7	36.80%	1	5.30%
Doctoral student	2	18.20%	3	27.30%	5	45.50%	1	9.10%
Teacher	8	21.10%	11	28.90%	10	26.30%	9	23.70%
Faculty staff	5	16.70%	4	13.30%	7	23.30%	14	46.70%
Total	18		26		29		25	

As seen on Table 7c, while the sample sizes of application groups were compared, faculty staff's applications (46.70%) have more share as percentage in large sample size groups, in comparison to other executors. Also, it is seen that the other executors have opted for the group with the sample size in the range of 21-50.

Research Findings Concerning the Fifth Sub-Question of the Study

In this study, the results of the analysis that answered the question "is there a significant difference between size effects of the studies according to sample sizes" were presented on Table 8.

Table 8. The Effect Size Differences According to Sample Size

Model Random Effects Model	N	Hedges's g	%95 Confidence Interval		Heterogeneity test	
			Lower	Upper	Q-value	P
1-20 people	18	0.97	0.55	1.38		
21-30 people	26	0.84	0.62	1.06		
31-50 people	29	0.94	0.71	1.18		
51 and more	25	0.59	0.22	0.95		
Total Between*					2.85	0.41

* How accurate is the sample size variable in explaining total variance

As seen on Table 8, average effect size on achievement of experiment groups, whose sample size consisted of 1-20 persons, was found 0.97. This value was found 0.84 for groups that had 20-31 persons, 0.94 for groups that had 31-50 persons and 0.59 for groups that had more than 51 persons. Heterogeneity test was applied in order to find whether there is a significant difference between effect sizes. According to the test result, no significant difference was identified (Q=2.85, p>.05). Accordingly it can be said that sample sizes of the PBL groups have no significant effect on student achievement.

Research Findings Concerning the Sixth Sub-Question of the Study

In the following, Table 9 presents results of the analysis in order to answer another research question of the study: "is there a significant difference between effect sizes of the studies with regard to the scientific field where PBL was applied?"

Table 9. The Effect Size Differences According to the Scientific Field

Model Random Effects Model	N	Hedges's g	%95 Confidence Interval Lower	Upper	Heterogeneity test Q-value	p
Sciences	58	0.90	0.69	1.12		
Social Sciences	14	0.89	0.48	1.29		
Mathematics	15	0.86	0.31	1.40		
Health Sciences	8	0.49	-0.22	1.22		
Computer Sciences	3	-0.03	-1.08	1.02		
Total Between*					3.91	0.41

* How accurate is the scientific field variable in explaining total variance

As seen on Table 9, effect sizes according to different scientific field in terms of random effects models are the following: Sciences 0.90; Social Sciences 0.89; Mathematics 0.86 and Health Sciences 0.49. In addition, meta-analysis indicated that studies in the fields of Computer Sciences (-0.03) had negative effect size. Heterogeneity test was applied in order to find whether there is a significant difference between effect sizes concerning the scientific fields where PBL was used. It was found out that there is not a significant difference between average effect sizes of the studies in terms of academic achievement (Q=3.91; p>.05). Research findings demonstrated that level of achievement does not vary as a result of PBL applications that were done in different scientific fields.

Research Findings Concerning the Seventh Sub-Question of the Study

In the study, results of the analysis done in order to acquire findings are presented on Table 10, concerning the question "is there a significant difference between effect sizes of the studies according to the education levels of the students where PBL was applied".

Table 10. The Effect Size Differences According to the Education Level

Model Random Effects Model	N	Hedges's g	%95 Confidence Interval Lower	Q-value	Heterogeneity test Q-value	P
Primary school	4	0.24	-0.81	1.29		
Secondary school	26	1.03	0.71	1.34		
High school	23	0.99	0.56	1.41		
Undergraduate	45	0.69	0.47	0.90		
Total Between*					4.86	0.18

* How accurate is the education level variable in explaining total variance

As indicated on Table 10, in accordance with the random effects model, average size effect value with regard to academic achievement was found 0.24 for primary school level, 1.03 for secondary level, 0.99 for high school level and 0.69 for undergraduate level. Heterogeneity test was applied in order to find whether there is a significant difference between effect sizes of the meta-analysed studies according to education level. This test results indicated that there is no significant

difference between effect sizes of the studies (Q=4.86; p>.05). In other words, there is homogeneity between effect sizes of the studies and level of achievement does not vary as a result of PBL applications that were done in different education levels.

Research Findings Concerning the Eighth Sub-Question of the Study

Next, Table 11 presents results of the analysis in order to answer another research question of the study: "is there a significant difference between effect sizes of the studies with regard to the PBL's application time?"

Table 11. The Effect Size Differences According to the Application Time

Model	N	Hedges's g	%95 Confidence Interval		Heterogenety test	
Random Effects Model			Lower	Upper	Q-value	P
3-16 h.	34	0.98	0.68	1.28		
17-48 h.	37	0.77	0.54	1.00		
49 h. and more	22	0.63	0.22	1.04		
Unspecified	5	1.12	0.73	1.51		
Total Between*					4.10	0.25

* How accurate is the application time variable in explaining total variance

As seen on Table 11, in accordance with the random effects model, size effect of the applications that lasted 3-16 hours was found 0.98. This value was found 0.77 for applications that lasted 17-48 hours and 0.63 for applications whose duration was over 49 hours. In the study, effect size of the studies, which did not report PBL application time, was determined 1.12. Heterogeneity test was applied in order to find whether there is a significant difference between effect sizes of the meta-analysed studies according to application time per hour. The test results showed that there is no significant difference between effect sizes of the studies (Q=4.10; p>.05). Accordingly, the effects of PBL on academic achievement do not change according to application time, whether it is long or short.

Discussion, Conclusion and Suggestions

This meta-analysis study benefited from research findings of 98 studies. The study investigated PBL approach's effects on students' academic achievement when compared to traditional teaching.

When the publication years of the study included in the meta-analysis, between 1997 and 2010, there is growing number of studies analysing the effects of PBL on achievement; however after 2012, this acceleration was replaced by a decrease. In this point, this meta-analysis study is both seasonable and necessary for the relevant literature. Because the above-mentioned decrease in number of studies might indicate that there is sufficient number of studies on the subject and therefore recently researchers might tend to do studies on different topics.

Among the studies were included in the meta-analysis, different from the studies which have specified that a positive effect on PBL when compared to traditional teaching (Tozo, 2011; Tavukçu, 2010; Ukoh, 2010), in some studies, it has concluded that there is a negative effect or no effect (Kazemi and Ghoraishi, 2012; Koçakoğlu, 2008; Scott, 2005). Also, meta-analysis results of the studies done before the 2000's investigating PBL's effects on student achievement or on their knowledge levels indicate that PBL had no or insignificant effects on student achievement or on their knowledge levels (Vernon and Blake, 1993; Berkson, 1993, Colliver, 2000). In a recent meta-analysis study, Leary (2012) found size effect value close to medium level (0.45). In Üstün's (2012) study which has been included 52 studies made in the field of science, it has been determined that there is a high level effect (g=0.82) according to PBL as compared to traditional teaching on achievement. In addition, Batdı's (2014) results of his meta-analysis study have reached that PBL has a very high level effect on achievement as compared to traditional teaching. When it has been looked at these results obtained which are different from each other, it is important to clarify PBL's effects on academic achievement. For this

purpose, in the light of the second sub-question of the research, heterogeneity test was done in order to determine meta-analysis model of the study. According to the results of heterogeneity test, distribution of size effect is heterogeneous (or not homogeneous). Therefore, the study preferred random effects model instead of fixed effects model. According to random effects model, average size effect of the meta-analysed studies was calculated 0.83. With regard to this finding, PBL has medium-level effects (Cohen, 1988) in terms of increasing academic achievement. In order to validate this finding, Classic Fail-Safe N analysis, which determines the power of meta-analysis study, was employed. The analysis produced results that confirmed validity of the meta-analysis study.

In the present study, it has been determined that the factors influencing PBL's effect size on achievement according to traditional teaching have been examined. In order to determine factors, the pre-studies which investigated the effectiveness of PBL approach have been examined and the factors that influence the approach described in these studies are listed as follows: Factors related to executors, sample size, field of science and application time (Leary, 2012; Walker and Leary, 2009; Dochy, Segers, Van den Bossche and Gijbels, 2003; Kaufman and Mann, 1999). Determined factors were assigned as mediator variables of the study. It is thought that the independent variables of the study will be useful in determining whether there is a significant difference between effect sizes of the meta-analysed studies and in interpreting effective and ineffective features of these findings with regard to PBL's effects on student achievement. In addition, by this means the reasons for insignificant/negative effects of the analysed studies (Hatısaru and Küçükturan, 2011; Carrio, Larramona, Banos and Perez, 2011; Şahin and Yörek, 2009) which determined PBL's effects as negative or neutral and caused average effect size to be medium level can be questioned.

In the study, heterogeneity test was done in order to reveal publication bias status of the study. In this framework, it was found that effect sizes of meta-analysed studies with regard to PBL's effects on academic success, do not change according to their publication status (published/unpublished). In other words, average effect size values of the published studies and average effect size values of the unpublished studies were close to each other. No significant difference was identified in this matter; therefore it can be said that there is no publication bias in the study. In order to clarify and validate publication bias status of the study, funnel graphic and Begg and Mazumdar's rank correlation test were employed. Consequently, all three analyses indicated that there is no publication bias in this study. These analyses, indicating that there is no publication bias, are considered as replies to future criticisms of this meta-analysis study. Thus, the aim of this study not reach a conclusion in favour of PBL but to collect findings of previous studies (which meet criteria for the analysis) on this subject and to find out a general opinion about PBL's effects on achievement when compared to traditional teaching .

In the meta-analyse study, PBL applications were executed by teachers, faculty staff, master's students or doctoral students. The fifth sub-question of the study investigated whether there was a significant difference between effect sizes of the studies according to the executors. For this purpose, heterogeneity test was done. The test results indicate that there was a significant difference between acquired effect sizes according to the PBL's executors. In analysing this difference, it was found out that PBL was the most effective in the studies done by teachers and master's students whereas PBL was the least effective in the studies done by faculty staff. According to the effect size values (Cohen, 1988), it was identified that PBL's effects on achievement as compared to traditional teaching was high-level in the studies of teachers, doctoral and master's students. However, effect sizes of faculty staff's studies were found low.

In order to examine the reasons behind this low value, descriptive analysis was made. According to descriptive analysis results, master's and doctoral students did their own studies as researchers with a large percentage. However, the situation of the faculty staff and teachers is opposite to the situation of masters' students and doctoral students. They carried out the PBL applications as an official teacher of the course with researchers' control with a large percentage. The study also looked at application time and sample sizes and found out that, in comparison to master's students and doctoral students, faculty staff work on bigger sample groups in a longer period of time.

When researchers did applications on their own, they are expected to adapt a flexible, self-prepared and self-regulated program. They are also expected to be motivated more than class teachers'; therefore their applications might bring more productive results. However, even PBL's executor and researcher is the same person, if the application class is not his or her own class, validity of the study might be influence by this situation. In this case, students are aware of the experiment. Moreover, if the applications are short-term, students can be influenced from different teachers and changes in learning process. In this point, student achievement after PBL application can be higher than expected under normal conditions. In order to avoid this situation, two suggestions are made (Kocakaya, 2011): Firstly, PBL's application time should be long, so that student can adapt this new approach, new student, new process and new teaching conditions and regard these new situation as normal. Secondly, a particular time after the experimental study, a scale such as retention test or recognition test can be applied to students. The difference between the results of these tests should be compared. Preferring long-term applications is important in terms of the validity of the study; however research findings indicate that faculty staff mostly did long term applications covering 49 hours (3 months) and effect size of the approach on achievement was found low. Nonetheless, in order to obtain an effective result from the application, it is necessary for students to adapt the PBL approach. In doing so, it is indicated that students need a time period of about 6 months (Schultz-Ross and Kline, 1999, cited in. Yadav, Subedi, Lundeberg and Bunting, 2011). However, 6 months is a long time period and most of researchers cannot spare this time for PBL applications. In addition, long-term application might cause students to lose their attention to the courses (Kocakaya, 2011). In this point, findings acquired from teachers, who are among the executors, have become important.

In applications done by teachers, PBL's effect size on achievement was found a high-level. Unlike masters' students and doctoral students who achieved high level success like teachers, teachers did their application in their official classes. Accordingly, the studies carried out by both researches themselves and official teachers of classes, can be obtained high achievement. In this case, experimental groups that were determined for experimental studies should not be selected from different schools but from the schools where researchers are also formal teachers; so that experimental study can be more productive (Kocakaya, 2011). As researchers are considered as persons who have more information about the subject, application of PBL in researchers' own classes are among the factors that bring success. In addition, the other findings obtained from the descriptive analysis showed that the number of applications in the range of 17-48 hours and 21-50 sample size are more than the others. Based on these findings obtained, in comparison to bigger sample groups, applications in smaller sample groups play a considerable role in terms of gaining the control of the classroom. Moreover, smaller groups facilitate execution of PBL's all stages in accordance with the plan. This might be more successful. Instead of long-term applications, higher student achievement may have obtained from the applications in 4-12 weeks (17-48 hours), because students' interest to the course and the approach is kept alive. Consequently, PBL applications should be applied in researchers' own classes, if there are any. An optimum sample size should be selected in order to execute application plan without any problems. The application should take less than 3-4 weeks or should not exceed duration of a semester. It can be said that all these factors increase student achievement. However, these comments according to the descriptive analysis of the study are not supported by the results of the analysis of mediator variables. According to this analysis, sample size or application time is not effective to increase student achievement with PBL as compared to traditional teaching. Therefore, these comments based on the descriptive analysis, although there is no significant difference according to the mediator variables, can be useful in helping researchers to execute the PBL approach better in studies.

In the study, heterogeneity test was applied in order to find whether there is a significant difference between effect sizes according to the experiment groups' sample sizes where PBL was applied. According to test result, no significant difference was identified between the groups. It was found out that sample sizes of the PBL groups, whether they are big or small, have no significant effect on student achievement. In other words, the number of students, whether few, medium or many, do not affect student achievement. There are several meta-analysis studies in the literature investigating the effects of different learning approaches on student achievement; these studies support this research finding. (Gözüyeşil, 2012; Şahin and Tekdal, 2005). Gözüyeşil (2012)'s meta-analysis study, in which he explored the effects of brain-based learning on academic achievement, investigated the effect size of the brain-based learning on student success and analysed if these values show significant differences in terms of sample sizes of the studies. Sample sizes of the meta-analysed studies were grouped as small (1-49), medium (50-99) and big (100 and more). In the final analysis, it was found that the effects of the approach on achievement do not vary according to sample sizes. Sample sizes of the experiment groups of the meta-analysed studies were examined and it was identified that most of the groups consisted of more than 15 and less than 50 individuals. The small sample size of these studies might depend on the fact that researches were often done in fixed classrooms. Small number of students in pre-graduate levels also played a role. In the study, although sample sizes did not included many individuals, examined experimental models seem to prove that studies produced credible results. In conclusion, it can be said that effect size value is not affected by sample sizes of the meta-analysed studies.

The other heterogeneity test was applied in order to find whether there is a significant difference between effect sizes concerning the scientific fields where PBL was applied. It was found out that there is not a significant difference between the groups. In other words, PBL's application in different scientific field does not affect student achievement levels. Also, it is interesting that, as distribution of meta-analysed studies according to scientific fields is considered, there are only few studies in other fields. Therefore it is thought that, the interest that was showed to natural sciences should be showed to other fields as well. Walker and Leary (2009) did meta-analysis of PBL. In their research, they compared effect sizes of the meta-analysed studies according to scientific fields. They emphasised most studies were done in Health Sciences and they called for more studies particularly on the fields of Social Sciences and teachers training. In conclusion, PBL might seem to fit more to the fields of Sciences and Health Sciences as it stipulates doing research on a particular problem, making proper decisions and reaching a conclusion. However, many studies indicate that PBL can be applied to other fields as well (Tsai and Shen, 2009; Luck and Norton, 2004; Doucet, Purdy, Kaufman and Langille, 1998).

In the study, heterogeneity test was applied in order to find whether there is a significant difference between effect sizes of the meta-analysed studies according to education level. This test results indicated that there is no significant difference between effect sizes of the studies. In other words, PBL applications in primary school, secondary school, high school or graduate level do not affect students' level of achievement. When research findings are interpreted on the basis of cognitive developmental stages of students concerning their education levels, size effect levels that were obtained from PBL can be explained. According to Piaget's cognitive developmental stages, a primary school student is on concrete operational level. General features of this level indicate that thinking processes of students depend on real, observable events. Student can solve complex problems if they are concrete. However, they fail to solve abstract problems. However, from adolescence or approximately secondary school age in terms of education levels, students' way of thinking reach adults' level and students are thought to do hypothesis based-deductive operations. Therefore students in this level are not limited to solve problems by doing operations with objects. They can develop hypotheses, think through deduction and induction and systematically reach solutions (Piaget, 1964). When the steps of PBL are examined, this approach is appropriate for students who are on the level of abstract thinking. Thus, research findings show that effect size values of studies done in primary school level were low. However, this situation is not interpreted as PBL should not be applied in primary school, because in this study PBL's effect sizes were determined low for graduate students as well. Primary school years influence next steps of education. If schools secure development of cognitive behaviours for each student in the first two or three years of the primary school, students are expected to present more positive improvements in terms of cognitive and affective skills in their later learning stages (Bloom, 1956). Therefore, PBL is a necessary application for primary school level as well however teaching-learning processes should take students' development skills into consideration. Application of PBL approach particularly during courses with young students will help student to adapt PBL into real life conditions. In doing so, searching, learning and problem solving individuals can be created. As students use PBL in their real lives, they will also have basis for future PBL applications in the next education levels.

Finally, significant difference between effect sizes of the meta-analysed studies was investigated according to application time per hour. In doing so, heterogeneity test was applied. The test results showed that there is no significant difference between effect sizes of the studies. Research findings demonstrate that the effects of PBL on academic achievement do not change according to application time, whether it is long or short. However in order to achieve generalisable experimental studies, long-term studies were considered better than short-term ones. In long-term applications, students may get bored with PBL and this factor should be taken into consideration. Despite meta-analysis studies supporting this result (Üstün, 2012; Özdemirli, 2011), there are studies indicating that PBL's application time causes changes on PBL's effects. In Üstün's (2012) study, PBL applications are grouped as 0-5 weeks, 6-10 weeks and 10 weeks over. It has been reached that in terms of application time, the overall effect size of PBL as compared to traditional teaching is not differ. Besides, there are studies which have been indicated that the overall effect size is differ in terms of application time. For example in a study done by Kazemi and Ghoraishi (2012), it was found that in traditional education system, PBL was not effective on student achievement in short applications that last one month or two months. However, they urged that successful results can be achieved for longer applications that last three months (12 weeks, approximately 48 hours and more). In their research, Kazemi and Ghoraishi applied three mathematics tests in the experimental group after each month: test 1, test 2 and test 3. The results of these tests indicate a significant difference in terms of student achievement. In order to find out which test caused the difference, LSD test was made. This test showed that there was no significant difference between the results of test 1 and test 2, however it identified a significant between the results of test 3 and the first two tests in favour of test 3. Therefore it was found that PBL is not effective in short-term applications.

In short-term applications (1-16 hours) student evaluate knowledge before they forget it. This situation can be criticised as their level of achievement is initially higher. Nevertheless, research findings of the studies, investigating students' retention levels of knowledge or PBL's effects on knowledge persistence, showed significant results in favour of PBL (Çelik, Eroğlu and Selvi, 2012; Wong and Day, 2009; Özgen, 2007). In studies, which limited application time to a relatively short duration, retention test was made. According to the test results, in PBL applications students did not memorise information but learn by explaining the meaning. Strobel and Barneveld (2009) did meta-analysis of the meta-analysed studies. In their study, they urged that PBL is superior to traditional approaches in terms of storing information for long-term and converting it into skills. According to their research findings, PBL does not direct student to memorise information; instead it is effective in terms of retaining knowledge and making it permanent. On the other hand, long-term PBL application may decrease student achievement or not to increase it, because students are not aware of PBL approach or do not know much about it or they begin to feel deficiencies of PBL's difficulties in time (Yadav et. al., 2011). In PBL approach, students can feel uncomfortable or disappointed as they cannot reach ready information as they previously did in traditional learning. Therefore, students should have basis for PBL before the application in order to be successful during the process. In addition, to achieve higher student achievement, best approach should be determined by the teacher instead of depending on a single approach. Therefore, regulation of course in this manner may contribute student achievement in a positive way. Teachers should not rely on a single theory or approach; instead they should have extensive knowledge about all principles of learning theories; so that they can be capable of applying necessary learning approach whenever needed (Ertürk, 1979; Dewey, 1997).

In summary, when results of the study are taken into consideration on the basis of meta-analysis, it can be considered that PBL is positively effective on students' academic achievement. Thus, it was found out that PBL has high-level effects on achievement. In addition, according to the findings of the study obtained from the sub-questions, it can be said that PBL is effective in Social Sciences, Mathematics, Computer, and Health Sciences courses as much as in the field of Science courses. Also, particularly in terms of providing the validity of the study, research findings demonstrate that PBL applications should be made by researchers' own classes with their own students if possible. However examination of meta-analysed studies indicates that this situation is not always possible. Therefore, it was considered more appropriate that researchers choose class teachers and make these teachers to do PBL applications. In situations that is not even possible, application should be long-term so that students can adapt different teachers and different learning processes. If these long-term applications are not done, it is important to do recognition test in such studies. However, it is equally important for students not to be aware of the fact that they are in an experiment process. This situation is significant for the validity of the studies. Research findings of these studies also support these interpretations. Other research findings indicate that, PBL is convenient for all education levels with the condition that a particular problem status is determined in accordance with students' development levels. In addition the study produced results that students may lose their attention during applications which last more than 3 months or they get bored of PBL. In order to prevent this situation, the course should be supported with different approaches whenever they are compatible with the subject during teaching-learning processes. Nonetheless, in order to adapt students to PBL approach and to prevent them from losing attention, first of all they should not be alienated from PBL process. In addition, students should be obtained PBL basis from young ages. When all these above-mentioned warnings concerning PBL application process are taken into consideration by researchers and educators, it can be said that PBL's effects on achievement can rise to higher levels. Research findings of the study show that, application of PBL during teaching-learning process can help to give information about how students' achievement levels are affected. Moreover, through descriptive analysis tables, insufficient points of this subject in the literature can be identified.

The present study is limited by the research reports made in Turkey and abroad and which had an experimental design with control group (In control group, traditional teaching; in experimental group, PBL approach has been used in these studies). Also the published (articles) and unpublished (masters' an doctoral thesis) studies were included in the meta-analysis of the study, which can be reached and which are compatible with the predefined criteria. In the light of this study's results, these suggestions were made:

1. This meta-analysis study only included data of studies which were concerned to find out students' academic achievement. Therefore, in the fields of Health Sciences and Computer Sciences, the skills for fulfilling field-oriented performance were given priority before student achievement. Therefore, there are a few studies analysing student achievement in these fields. Nonetheless there are a few studies in the fields of Social Sciences and Mathematics as well. For this reason, this study calls for more studies concerning PBL application and investigating student achievement, particularly in the fields of Social Sciences and Mathematics
2. Such application studies towards students on graduate level are off course important for students in terms of giving information to them on PBL, however it should be kept in mind that learning by searching, interpreting and problem solving can turn to skills only if they are obtained during young ages. Therefore more research should be done towards young students in order to raise individuals who adapt PBL in their lives, use it outside of school and solve problems.

3. The study evaluated PBL's effectiveness according to traditional teaching only in terms of student achievement. For this reason, the study calls for more meta-analysis studies analysing PBL's effectiveness on students' affective properties and psychomotor skills. It is though that especially curriculum development specialist can benefit from research findings of these meta-analysis studies.
4. Instead of applying PBL in long-term periods such as all semester or half-semester, it should be done in intervals on a particular course. The most convenient topics of courses should be selected and adapted to PBL. In doing so, it is thought that PBL's effectiveness on student achievement can be increased. By this means, students do not lose their attention and preserve their learning interests concerning the particular course and subject.
5. Studies aiming PBL's effects on a single variable should not less than 4 weeks (1 month) if they do not include retention and recognition tests.
6. Today, we witness that accumulation of knowledge increase rapidly. Therefore it is suggested that studies include research techniques such as meta-analysis method, which allows combination and interpretation of different research findings of similar individual studies. There are only a few meta-analysis studies, especially in Turkey. Therefore, it is important that researchers should focus on this field more. In addition, it is considered that when meta-analysis studies become widespread, researchers will become conscious about the application of this method and pay attention to share statistical information in their studies which are necessary to calculate effect size value.

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Appendix 1. Studies Included to the Meta-Analysis

No	Author	Year	Type of Study	ES*
1	Abdullah, N. I., Tarmizi, R. A. & Abu, R.	2010	Article	-0.32
2	Ajai, J. T., Imoko, B. I. & O'kwu, E. I.	2013	Article	0.12
3	Akın, S.	2008	Master's Thesis	0.68
4	Akınoğlu, O. & Tandoğan, R. Ö.	2007	Article	0.63
5	Alagöz, B.	2011	Article	1.48
6	Antepohl, W. & Herzig, S.	1999	Article	1.54
7	Araz, G.	2007	Master's Thesis	0.26
8	Arıcı, N. & Kıdıman, E.	2008	Article	-0.65
9	Aydoğdu, C.	2012	Article	1.17
10	Ayvacı, A.	2011	Master's Thesis	-0.09
11	Bayrak, R.	2007	Doctoral Thesis	1.63
12	Benli, E.	2010	Master's Thesis	2.15
13	Bilgin, İ; Şenocak, E. & Sözbilir, M.	2009	Article	0.04
14	Carrio, M., Larramona, P., Banos, J. E. & Perez, J.	2011	Article	-0.12
15	Charif, M.	2010	Master's Thesis	1.12
16	Çakır, T.	2007	Master's Thesis	0.93
17	Çelik, E., Eroğlu, B. & Selvi, M.	2012	Article	0.85
18	Çelik, P.	2013	Doctoral Thesis	2.13
19	Çelik, P., Önder, F. & Silay, İ.	2011	Article	1.13
20	Çetin, P.	2011	Master's Thesis	1.36
21	Çınar, D.	2007	Master's Thesis	2.85
22	Çiftçi, S., Meydan, A. & Ektem, I. S.	2007	Article	1.49
23	Demirel, M. & Turan, M.	2010	Article	0.72
24	Deveci, H.	2002	Doctoral Thesis	0.68
25	Diggs, L.	1997	Doctoral Thesis	1.17
26	Dobbs, V.	2008	Doctoral Thesis	-0.08
27	Doucet, M. D., Purdy, R. A., Kaufman, D. M. & Langille, D. B.	1998	Article	0.24
28	Drake, K. N. & Long, D.	2009	Article	0.26
29	Erdoğan, T.	2012	Doctoral Thesis	1.71
30	Folashade, A. & Akinbobola, A. O.	2009	Article	1.56
31	Göğüş, R.	2013	Master's Thesis	1.81
32	Gülseçen, S. & Kubat, A.	2006	Article	-0.17
33	Güneş, C.	2006	Master's Thesis	1.74
34	Günhan, B. & Başer, N.	2008	Article	0.94
35	Gürlen Erdem, E.	2011	Article	1.17
36	Gürpınar, E., Musal, B., Aksakoğlu, G. & Uçku, R.	2005	Article	0.61
37	Hatısaru, V. & Küçükturan, A. G.	2011	Article	-1.12
38	Hussain, M. A., Nafees, M. & Jumani, N. B.	2009	Article	2.13
39	Hwang, S. Y. & Kim, M. J.	2006	Article	0.15
40	Imanieh, M. H., Dehghani, S. M., Sobhani, A. & Haghighat, M.	2014	Article	0.21
41	İnce Aka, E.	2012	Doctoral Thesis	1.71
42	İnel, D.	2009	Master's Thesis	0.59

43	Jandric, G. H., Obadovic, D. Z., Stojanovic, M. & Rancic, I.	2011	Article	1.03
44	Kanlı, E. & Emir, S.	2013	Article	1.04
45	Kar, T.	2010	Master's Thesis	1.15
46	Karadaş, A.	2010	Master's Thesis	1.33
47	Karaöz, M. P.	2008	Master's Thesis	1.62
48	Kaufman, D. M. & Mann, K. V.	1999	Article	-1.48
49	Kazemi, F. & Ghoraishi, M.	2012	Article	0.13
50	Koçak, M. & Ünlü, M.	2013	Article	1.15
51	Koçakoğlu, M.	2008	Doctoral Thesis	-0.42
52	Kuşdemir, M.	2010	Master's Thesis	2.15
53	Marum, T.	2009	Master's Thesis	0.17
54	Masek, A. B.	2012	Doctoral Thesis	0.63
55	Mergendoller, J., Maxwell, N. L. & Bellisimo, Y.	2006	Article	0.94
56	Moralar, A.	2012	Master's Thesis	1.29
57	Mungin, R. E.	2012	Doctoral Thesis	0.19
58	Özdil, G.	2011	Master's Thesis	-0.41
59	Özeken, Ö. F. & Yıldırım, A.	2011	Article	0.16
60	Özgen, K.	2007	Master's Thesis	0.62
61	Özsarı, T.	2009	Master's Thesis	0.87
62	Penjvini, S. & Shahsawari, S.	2013	Article	0.09
63	Reynolds, J. M. & Hancock, D. R.	2010	Article	0.66
64	Rideout, E., England-O., V., Brown, B., Fothergill-B., F., Ingram, C., Benson, G., Ross, M. & Coates, A.	2002	Article	0.22
65	Sağır, S. U., Çelik, A. Y. & Armağan, F. O.	2009	Article	1.27
66	Sanderson, H. L.	2008	Doctoral Thesis	0.01
67	Sarıkaya, S.	2006	Master's Thesis	0.88
68	Scott, W.	2005	Doctoral Thesis	-1.06
69	Selçuk-Sezgin, G.	2010	Article	0.59
70	Selçuk-Sezgin, G., Karabey, B. & Çalışkan, S.	2011	Article	1.08
71	Serin, G.	2009	Doctoral Thesis	-0.11
72	Sevening, D. & Baron, M.	2003	Article	-0.59
73	Sindelar, T. M.	2010	Master's Thesis	0.08
74	Stephens, L. M.	2010	Master's Thesis	0.08
75	Sungur, S., Tekkaya, C. & Geban, Ö.	2006	Article	1.50
76	Şahbaz, Ö. & Hamurcu, H.	2012	Article	1.27
77	Şahin, A.	2011	Master's Thesis	0.92
78	Şahin, M.	2009	Article	1.22
79	Şahin, M. & Yörek, N.	2009	Article	-0.15
80	Şalgam, E.	2009	Master's Thesis	0.17
81	Şenocak, E., Taşkesenligil, Y. & Sözbilir, M.	2007	Article	0.42
82	Tarhan, L. & Acar, B.	2007	Article	1.77
83	Tarhan, L., Ayar-K., H., Öztürk-Ü., R. & Acar, B.	2008	Article	0.66
84	Taşoğlu, A. K.	2009	Master's Thesis	0.20
85	Tavukçu, K.	2006	Master's Thesis	1.57
86	Tosun, C.	2010	Doctoral Thesis	0.61

87	Tozo, A. T.	2011	Master's Thesis	1.18
88	Tüysüz, C., Tatar, E. & Kuşdemir, M.	2010	Article	2.09
89	Ukoh, E.	2010	Article	2.00
90	Uslu, G.	2006	Master's Thesis	1.94
91	Usoh, I. I.	2003	Doctoral Thesis	0.11
92	Usta, N.	2013	Doctoral Thesis	2.80
93	Uygun, N. & Tertemiz, I. N.	2014	Article	1.40
94	Van Loggerenberg-Hattingh, A.	2003	Article	0.24
95	Wong, K. K. & Day, J. R.	2009	Article	1.67
96	Yaman, S. & Yalçın, N.	2005	Article	0.72
97	Yıldız, N.	2010	Master's Thesis	0.38
98	Yurd, M	2007	Master's Thesis	1.35

* ES: Effect Size