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THE EFFECTIVENESS OF PROJECT-BASED LEARNING ON SCIENCE EDUCATION: A META-ANALYSIS SEARCH

Review Article

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Abstract

The present study aims to demonstrate, by means of a meta-analysis, the effectiveness of Project-Based Learning in the context of academic performance and various study characteristics. For this purpose, the relevant literature was reviewed to identify studies using Project-Based Learning in the fields of physics, chemistry, biology, and science. Following the literature review, the study characteristics and the criteria for their inclusion were determined. A total of 48 studies were included and, by means of the analyses conducted, the general effect size of Project-Based Learning in science education was found to be 1.063. This is quite a large effect size by Cohen's criteria and it shows that Project-Based Learning is 86% more effective in science education compared to traditional learning approaches. Project-Based Learning was found to have a great effect size in different subjects (physics, chemistry, biology, and science), at different levels (primary, secondary, and tertiary), and with samples of various sizes (small, medium, and large). Project-Based Learning can thus be deemed more effective compared to traditional learning approaches.

Keywords: Science education, Project-Based Learning, meta-analysis.

1. Introduction

Technological advancement plays an important role in the economic development of countries and the improvement of their living standards (Ayas, 1995; Bayındır, 2007; Ünal, Coştu, & Karataş 2004). Technological advancement, however, requires societies to have science literacy in order to have a say in the developing world and to have an outstanding position amongst successful nations (Korkmaz & Kaptan, 2001). In order for such a society to emerge, there appears to be an acute need for individuals with the ability to use science process skills, to solve problems in the face of the unknown, to establish cause-and-effect links by observing the settings that they are in, and to use high-level cognitive skills (Korkmaz & Kaptan, 2001; Köseoğlu, Tümay, & Budak, 2008). An effective science education plays a crucial part in raising such individuals, as one of the functions of science education is to enable students to develop into science-literate individuals (Çakıcı, 2009; Emrahoğlu & Öztürk, 2010; Ünal et al., 2004). The realization of an effective science education in turn depends on a sound science curriculum and its proper implementation (Ayas, 1995).

Many researchers have found that Project-Based Learning (PBL) is top of the methods that can be used in science classes to raise the quality of science education and to enable students to use their scientific knowledge and skills to solve problems in their daily lives and to become science-literate individuals (Barron et al., 1998; Dede & Yaman, 2003; Demirhan

& Demirel, 2003; Filippatou & Kaldi, 2010; Gillies & Ashman, 2000; Korkmaz & Kaptan, 2001; Liu & Hsiao, 2002; Şahin, 2009; Wolk, 1994) because PBL is a process that promotes individual learning, enables students to create links between school and life, supports lifelong learning, and encourages self-controlled learning (Dede & Yaman, 2003; Şahin, 2009). PBL is also thought to improve students' knowledge and skills, raising their academic performance. The literature includes studies highlighting the positive effects of PBL on students' academic performance in science education (Baran, 2007; Çeliker & Balım, 2012; Değirmenci, 2011; Ergül & Kargın, 2014; Güven, 2011; Hung, Hwang & Huang, 2012; İmer, 2008; Keskin, 2011; Nikbay, 2009; Özbek, 2010; Serttürk, 2008; Tortop, 2010; Wolk, 1994; Yurttepe, 2007). However, there are also studies which have found no change in students' academic performance in science education (Ayan, 2012; Dilşeker, 2008; Ekiz, 2008; Gültekin, 2009; Özer & Özkan, 2011; Özer & Özkan, 2012; Özahioğlu, 2012; Toprak, 2007; Tuncer & Taşpınar, 2010). Furthermore, while PBL was found by Çil (2005) to have a positive effect on eighth-year students' academic performance in science, it was shown to make no significant difference in seventh-year students' performance. The literature contains many studies with conflicting views on the effects of PBL on student performance, but none on its effectiveness or on the consideration of its effects taking several variables into account.

Disagreement on the effects of Project-Based Learning on student performance in science education has highlighted the need for studying the effectiveness of this approach. For this purpose, the current research was designed to find any effectiveness that Project-Based Learning might have in the context of students' academic performance in science education. A meta-analysis was conducted to interpret the conclusions of the studies on PBL in the literature.

2. Method

2.1. Research Model

A meta-analysis was used in this study to determine whether PBL was effective in science education. The meta-analysis method involves literature review that combines and re-interprets the conclusions of similar individual studies in a given field (Hunter & Schmidt, 1990). Although many literature review methods exist, meta-analysis differs from them in that it is based upon statistical techniques and numerical data (Baran, 2007). Meta-analysis is used more and more often especially in many domains of social psychology, playing a crucial role in understanding social policies (Durlak & Lipsey, 1991). Meta-analysis has many different types but the present study used 'Study Effect Meta-Analysis'.

2.2. Data Collection

First, in line with the research objective and methodology, the inclusion criteria were determined by the researcher. The following criteria were used to identify the studies to be included in the meta-analysis:

- The studies were to use a pre-test / post-test control group model,
- They were to focus on the effects of PBL on students' academic performance,
- They were to report the sample size (n), arithmetic mean ($\overline{X}$), and standard deviation (sd) values for the experiment and control groups, which would make the calculation of the effect size possible, or include data by which these values could be calculated.

After the study criteria for the meta-analysis were determined, a literature review was carried out and the selection of the studies to be included was initiated. The literature review began primarily by national studies. To this end, the Ulakbim and YÖK (Higher Education Council) databases as well as journals from faculties of education and congress and symposium papers were examined.

In order to reach international studies, the EBSCO, ERIC and Proquest databases were searched online with the intention to increase the number of studies to be included in the meta-analysis. In this context, these databases were searched with the keyword 'Project-Based Learning'. 1,059 studies showed up on the Proquest database and 418 on the ERIC database.

After this literature review, the studies were all checked one by one for suitability for the study criteria. In this process, those studies on science education with a pre-test and post-test control group experimental pattern, academic performance measurement, and standard deviation and arithmetic mean were included in the meta-analysis. Studies considered to be unsuitable by the inclusion criteria were excluded from the meta-analysis.

The remaining studies were excluded from the meta-analysis because some of them were not on science education, some did not measure academic performance, and some did not include the necessary statistical data (standard deviation and arithmetic mean). The reasons for the exclusion of 82 dissertations are presented in Table 1.

Table 1. *Reasons for excluding studies from the meta-analysis*

Reason		Number of studies
	Computer	5
	Life science	4
	Social science	17
	Mathematics	10
	Geometry	3
	English	4
	Geography	1
	Statistic	1
	Electronic	2
	Religion	2
	Material development	2
	Visual art	5
	Planning and evaluation	1

Studies not measuring academic achievement	About attitude and risk taking	7
	About literacy	5
	About awareness	2
	About self-efficacy	2
	About epistemological belief	2
	About motivation	1
Missing statistical information	Missing data about control group	5
Studies with different experimental design	One group experimental design	1
	Total	82

The literature review yielded 113 dissertations of which only 31 were considered to be suitable by the meta-analysis inclusion criteria. 29 of these were master and 2 were doctoral theses. Of the 82 theses excluded, 57 were in different fields and 25 failed to either measure academic performance or contain sufficient statistical data (Table 1).

Likewise, the literature review yielded 79 papers. After each of them was checked for suitability by the inclusion criteria, most were excluded. Only 12 papers were deemed to be suitable for inclusion in the meta-analysis.

Apart from these, congress booklets, faculty of education journals, and social sciences journals were regularly screened. Of the studies found, some were registered on multiple databases, and some were non-experimental. These non-experimental studies were excluded from the meta-analysis. Some of the master's and doctoral dissertations on Project-Based Learning were found to have been published also as papers. Such dissertations were included in the meta-analysis as papers. In the end, a total of 48 studies were found to meet the inclusion criteria. Studies with different domains and different sample groups within the same research were taken as separate studies.

2.3. Data Analysis

The statistical data from different studies needs to be converted into a common unit of measurement – the effect size – in order to be interpreted as a whole (Şahin, 2005). The effect size is a standard measurement value used to determine the force and direction of a correlation in a given study. In this research, the effect size for each study and the combined effect size were calculated by using the Metawin 1.00 program (Rosenberg, Adams & Gurevitch, 1997). The Metawin program calculates the experiment and control group averages and the combined standard deviation values by using 'Hedges' d' for the average effect size and the general effect size of each study (Özdemirli, 2011). Furthermore, the random effects model was selected on the Metawin program to calculate the average effect size in this study. The random effects model calculates the effect size by considering both the inherent variance of the studies and the variance between studies (Okursoy, 2009). For all the calculations and graphs in data analysis, the Microsoft Excel 2007 program and the SPSS 18.0 program were used. The level of significance for all statistical calculations was accepted as .05 in the study.

Developed in 1977 by Cohen, the effect size is a standard measurement value used to determine the force and direction of a correlation in a given study and, for whatever is studied, it answers the question ‘How effective is it?’ (Okursoy, 2009). Found by dividing the difference between the experiment group and the control group by the combined standard deviation value of the two groups, the effect size value is between -∞ and ∞. Negative (-) values indicate a higher score for the control group while positive (+) values indicate a higher score for the experiment group (Özdemirli, 2011). The greater the difference between the two groups and the smaller the standard deviation is, the larger the value of the effect size becomes. The effect size of a study offers clues on the significance of the conclusions of that study. For instance, in a study with a statistically significant difference between the experiment and control groups, there may be no significant effect size between the groups (Ergene, 1999).

Even though the classification of effect sizes may vary, the effect sizes of the studies analyzed in this research were interpreted according to Cohen, who interprets effect size values as follows (Yıldız, 2009);

- If the effect size value is between 0.20 and 0.50, there is a **small-scale** effect,
- If the effect size value is between 0.50 and 0.80, there is a **medium-scale** effect,
- If the effect size value is greater than 0.80, there is a **large-scale** effect.

The present study aims to reveal the effectiveness of Project-Based Learning in the context of student performance in science education. By means of a meta-analysis, the conclusions of studies in the PBL literature were combined and interpreted. Through the meta-analysis, this paper seeks to answer the following questions:

1) Does Project-Based Learning have a positive effect on students’ academic performance in science education?

2) Is there a significant difference between the effect sizes of the publications in the Project-Based Learning literature depending on the publication type?

3) Is there a significant difference between the effect sizes of the publications in the Project-Based Learning literature depending on the selected subject (physics, chemistry, biology, and science)?

4) Is there a significant difference between the effect sizes of the publications in the Project-Based Learning literature depending on students’ education levels (primary, secondary, and tertiary)?

5) Is there a significant difference between the effect sizes of the publications in the Project-Based Learning literature depending on the sample size (small, medium, and large)?

6) Is there a significant difference between the effect sizes of the publications in the Project-Based Learning literature depending on the technique used (studies using PBL only vs studies using PBL in addition to another method)?

7) Is there a significant difference between the effect sizes of the publications in the Project-Based Learning literature depending on the publication status (published / unpublished)?

3. Findings

3.1. General Effect Size of the Effectiveness of PBL

The general effect size of the studies included in the research was found to be d=1.063 (Figure 1). According to Cohen (1977), this is quite a great general effect. For this general effect size, the corresponding value in the z table was found to be 86.6%. In other words, students receiving PBL education performed 86.6% better than those receiving education with traditional methods. Many studies on PBL in science education conclude that students receiving PBL education perform better than those receiving education with traditional methods (Baran, 2007; Çeliker & Balım, 2012; Değirmenci, 2011; Ergül & Kargın, 2014; Güven, 2011; Hung, Hwang & Huang, 2012; İmer, 2008; Keskin, 2011; Nikbay, 2009; Özbek, 2010; Serttürk, 2008; Tortop, 2010; Yurttepe, 2007). Therefore, it can be claimed that that the conclusion of this meta-analysis is in line with the conclusions of other studies using PBL.

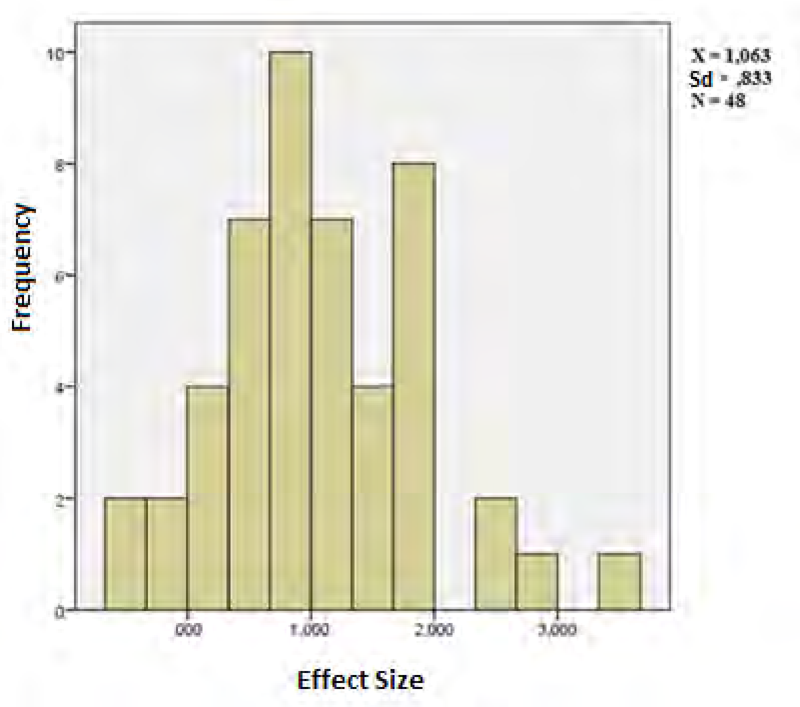

Figure 1. General effect size of the studies included in the meta-analysis

3.2. Effectiveness of PBL Depending on Publication Type

In this meta-analysis, 32 articles, 14 master's theses, and 2 doctoral theses that met the inclusion criteria were analyzed. The effect sizes in all publication types were found to be large (Table 2). According to the findings, the largest effect size was found in the doctoral dissertations (d=1.8957). The effect size was calculated as d=1.0497 for the master's theses and as d=0.8830 for the articles. The analysis results suggest that there are no statistically significant differences between the average effect sizes depending on different publication types (Q_B=3.6372; p>0.05).

Table 2. *Effect sizes of the studies depending on publication type*

Variable	Homogeneity between groups (Q_B)	n	The Overall mean effect size d	d for %95 CI Lower	Upper	Homogeneity within groups (Q_{WI})
Type of publication	3,6372					
Article		14	0,8830	0,5191	1,2469	60,1970
Master thesis		32	1,0497	0,8026	1,2969	238,1288
PhD dissertation		2	1,8957	0,9141	2,8773	0,0000

3.3. Effectiveness of PBL Depending on Selected Subject

In order to examine the effect of different subjects on the effect size, the studies were grouped into four categories: those conducted in physics, chemistry, biology, and science. Looking at the average effect sizes of these four categories, it can be argued that PBL has a great effect in all subjects. The largest effect size (d=1.3638) was found in biology (Table 3). The analysis results suggest that there are no statistically significant differences between the average effect sizes depending on different subjects (Q_B=1.3627; p>0.05).

Table 3. Effect sizes of the studies depending on selected subject

Variable	Homogeneity between groups (Q_B)	n	The Overall mean effect size d	d for %95 CI Lower	Upper	Homogeneity within groups (Q_{WI})
Subject area	1,3627					
Science		35	0,9738	0,7306	1,2169	236,4182
Chemistry		2	1,0101	-0,0047	2,0248	0,0084
Physics		6	1,1476	0,5587	1,7365	33,9053
Biology		5	1,3638	0,7116	2,0160	36,2566

3.4. Effectiveness of PBL Depending on Education Level

In order to examine the effect of the education level on the effect size, the studies were grouped into three categories: those conducted in primary, secondary, and tertiary education. PBL was found to be highly effective in secondary education (d=1.7677), primary education(d=0.9638) and tertiary education (d=0.9089) (Table 4). The analysis results suggest that there are no statistically significant differences between the average effect sizes depending on different education levels (Q_B=6.0919; p>0.05). The effectiveness of Project-Based Learning in all levels demonstrates that it can be used more frequently in all levels.

Table 4. *Effect sizes of the studies depending on students' education level*

Variable	Homogeneity between groups (QB)	n	The Overall mean effect size d	d for %95 CI Lower	d for %95 CI Upper	Homogeneity within groups (QWI)
Education level	6,0919					
Primary school		33	0,9638	0,7275	1,2001	213,2403
Tertiary		10	0,9089	0,4820	1,3359	59,8492
Secondary school		5	1,7677	1,1502	2,3852	12,8727

3.5. Effectiveness of PBL Depending on Sample Size

While including the studies in the meta-analysis, differences were noticed between their sample sizes. Therefore, sample size was added to the study characteristics. In this context, the studies included in the meta-analysis were grouped into three categories depending on their sample size: small ($n \leq 50$), medium ($51 < n \leq 100$), and large (n>100). A great majority of these studies had a medium-scale sample size (n=27). Project-Based Learning was found to be effective mostly in studies with a small-scale sample size (d=1.2314) (Table 5). Studies with medium- and large-scale sample sizes were found to have effect sizes of d=0.8984 and d=1.2013, respectively. The analysis results suggest that there are no statistically significant differences between the average effect sizes depending on different sample sizes (Q_B=2.4148; p>0.05).

Table 5. *Effect sizes of the studies depending on sample size*

Variable	Homogeneity between groups (Q_B)	n	The Overall mean effect size d	d for %95 CI Lower	Upper	Homogeneity within groups (Q_{WI})
Sample size	2,4148					
Small		18	1,2314	0,8855	1,5773	76,0539
Medium		27	0,8984	0,6305	1,1663	211,4180
Large		3	1,2013	0,4277	1,9750	18,9237

3.6. Effectiveness of PBL Depending on Techniques Used

Of the studies included in the meta-analysis, 40 used Project-Based Learning only whereas 8 complemented PBL with other techniques. The average effect sizes were then calculated for PBL and PBL plus other techniques (Table 6). While the average effect size for the group with PBL only was d_{PBL}=1.0205, it was found to be $d_{PBL+other}$=1.1086 for the group with PBL and another technique. A high level of effectiveness was detected in both techniques. The results suggest that there are no statistically significant differences between the average effect sizes depending on the use of PBL only or PBL and other techniques (Q_B=0.1018; p>0.05).

Table 6. *Effect sizes of the studies depending on techniques used*

Variable	Homogeneity between groups (Q_B)	n	The Overall mean effect size d	d for %95 CI Alt	Üst	Homogeneity within groups (Q_{WI})
Study design	0,1018					
PBL		40	1,0205	0,7950	1,2461	278,6000
PBL and other techniques		8	1,1086	0,6168	1,6004	40,2038

3.7. Effectiveness of PBL Depending on Publication Status

As for the publication status of the studies, 14 published and 34 unpublished studies were included in the meta-analysis. The average effect sizes for published and unpublished studies were found to have quite high values ($d_{published}$=0.8831 and $d_{unpublished}$=1.1020) (Table 7). No significant difference was detected between the average effect sizes of published and unpublished studies (Q_B=0.9228, p>0.05). In other words, there is no publication bias.

Table 7. *Analysis results on effect size differences between the studies depending on publication status*

Variable	Homogeneity between groups (Q_B)	n	The Overall mean effect size d	d for %95 CI Alt	Üst	Homogeneity within groups (Q_{WI})
Publishing status	0,9228					
Published		14	0,8831	0,5098	1,2563	60,1970
Unpublished		34	1,1020	0,8565	1,3475	260,2372

4. Results and Discussion

The general effect size of the studies included in the research was found to be d=1.063. According to Cohen (1977), this is quite a great general effect. For this general effect size, the corresponding value in the z table was found to be 86.6%. In other words, students receiving PBL education performed 86.6% better than those receiving education with traditional methods. Many studies on PBL in science education conclude that students receiving PBL education perform better than those receiving education with traditional methods (Baran, 2007; Çeliker & Balım, 2012; Değirmenci, 2011; Ergül & Kargın, 2014; Güven, 2011; Hung, Hwang & Huang, 2012; İmer, 2008; Keskin, 2011; Nikbay, 2009; Özbek, 2010; Serttürk, 2008; Tortop, 2010; Yurttepe, 2007). Therefore, it can be claimed that that the conclusion of this meta-analysis is in line with the conclusions of other studies using PBL. In other words, it can be argued that PBL raises students' academic performance.

According to the findings from the three groups compared, the largest effect size was found in the doctoral dissertations (d=1.8957) and the smallest effect size was found in the articles (d=0.8830). No statistically significant difference was detected between the average effect sizes of articles, master's theses, and doctoral theses (Q_B=3.6372; p>0.05).

When the effect sizes were compared according to the subjects selected, the largest average effect size was found in biology (d=1.3638) and the smallest average effect size was found in science (d=0.9738). In other words, PBL was mostly effective in biology but still highly effective in physics, chemistry, and science. No statistically significant difference was detected between the average effect sizes depending on different subjects (Q_B=1.3627; p>0.05).

A great majority of the studies included in the meta-analysis were in primary education (n=33), followed by tertiary (n=10), and secondary education (n=5). Although only 5 studies were in secondary education, PBL was found to be most effective at secondary education level (d=1.7677). It was also quite effective in primary and tertiary education, with effect sizes of d=0.9638 and d=0.9089, respectively. However, no statistically significant difference was detected between the average effect sizes depending on different education levels (Q_B=6.0919; p>0.05).

Project-Based Learning was found to be effective mostly in studies with a small-scale sample size (d=1.2314), and still quite effective in studies with medium- and large-scale sample sizes. Studies with medium- and large-scale sample sizes were found to have effect sizes of d=0.8984 and d=1.2013, respectively. The analysis results suggest that there are no statistically significant differences between the average effect sizes depending on different sample sizes (Q_B=2.4148; p>0.05).

Of the studies included in the meta-analysis, 40 used Project-Based Learning only whereas 8 complemented PBL with an additional technique. While the average effect size for the group with PBL only was d=1.0205, it was found to be d=1.1086 for the group with PBL and another technique. A high level of effectiveness was detected in both techniques. The results suggest that there are no statistically significant differences between the average effect sizes depending on the use of PBL only or PBL and other techniques. Used alone or in combination with other techniques, PBL affects students' academic performance in a positive way.

Since studies with statistically significant findings are more likely to be published, published works are expected to have a greater average effect (Rosenthal, 1991; Cooper & Hedges, 1994). Publication status can be found by looking at the difference between the effect sizes of published and unpublished works (Ergene, 1999). The present meta-analysis included 14 published and 34 unpublished studies which met the criteria. The average effect sizes for both published and unpublished studies using PBL were found to have quite high values ($d_{published}$=0.8831 and $d_{unpublished}$=1.1020). No significant difference was detected between the average effect sizes of published and unpublished studies. In other words, there is no publication bias.

In addition to combining the findings of scientific studies, meta-analyses also give information on tendencies on the research topic. In this context, the tendencies revealed by the studies on PBL conducted between 2002 and 2014 can be summarized as follows:

- A great majority of the studies on PBL in science education were master's and doctoral dissertations and a large number of these were not turned into scientific articles. The fact that most of these studies (66.6%) were master's theses may partly explain why these theses were not turned into articles.
- A large majority of the studies on PBL in science education were conducted in Science (72.91%), which accounts for the prevalence of studies at primary education level over those at secondary and tertiary levels.
- The number of studies on PBL in science education peaked between 2007 and 2010, followed by the period between 2011 and 2014.
- In general, PBL was found to be used on its own in the studies examined (83.33%). Studies in which it was used in combination with other methods were in minority.
- In PBL studies, the use of tests developed by the researcher is more common (93.75%).

- PBL studies in science education used medium-scale samples ($51 < n \leq 100$).
- The time spans over which PBL studies were conducted varied in length. No clear-cut tendencies were observed.

Meta-analyses are also used to combine the findings of studies conducted independently of one another. Such findings can be summarized as follows;

- Project-Based Learning affects students' academic performance in a positive way.
- Publication status makes no difference on the studies meeting the research criteria.
- No statistically significant difference is detected between the average effect sizes of articles, master's theses, and doctoral theses. Publication types have large effect sizes.
- PBL practices are an effective method in the fields of science, physics, chemistry, and biology.
- PBL has a high effect value whether used on its own or in combination with other techniques.
- PBL studies yield positive results at primary, secondary, and tertiary education levels.
- The effectiveness of PBL practices are independent of the sample size. The approach is effective with small, medium, and large-scale samples.

5. Suggestions

1. Most PBL studies seem to be conducted at primary education level even though data suggests that the highest effect value is obtained in studies conducted at secondary level. This could justify using PBL more frequently at secondary and tertiary levels.
2. Most Project-Based Learning studies seem to involve an experiment group where only teacher-centred traditional teaching methods are employed. No comparisons seem to be drawn between Project-Based Learning and other student-centred approaches such as Argumentation-Based Learning and Problem-Based Learning. Future studies could focus on comparisons between innovative and student-centred teaching approaches in both experiment and control groups.
3. Great difficulties were encountered in looking into the general characteristics of the studies included in the meta-analysis. A great majority of the studies contained no sufficient information about their researchers. There was a lack of information especially about the education level and professional experience of the implementer, and whether they were the same person as the researcher. In many studies where implementation was not carried out by the researcher, whether the implementers were given any informative training was not mentioned, either. In some studies, the duration of implementation was not given clearly, if at all. Since the duration of implementation as well as the professional qualities of the implementer such as their professional experience and pedagogical field knowledge are crucial in determining the outcome of a study, such detailed information must be given in all studies.
4. The effect size calculated for this study ($d_{general}$=1,063) is a criterion for researchers in Project-Based Learning. In future PBL studies, researchers could compare the effectiveness of their research to the effect size value of the present study for an idea.
5. The effect size obtained in this study shows that, in science education, PBL is an effective method on quite a large scale similar to laboratory-supported teaching (d=1,063>0,80). In our country, apart from the present study, only two meta-analysis

studies were found in Problem-Based Learning and Laboratory-Based Learning. Therefore, measuring the effectiveness in science education of other student-centred teaching methods such as Argumentation-Based Teaching, Collaborative Teaching, Computer-Aided Teaching, and Brain-Based Teaching, and comparing the findings with those of the present study will make a difference in raising the quality of science education.

6. Again national studies were found to include no meta-analysis on the effectiveness of Project-Based Learning in other subjects (mathematics, English, art, music, etc.). For this reason, meta-analysis studies in different fields will be useful in revealing where Project-Based Learning is most effective.
7. All studies included in the current meta-analysis on PBL were found to use only multiple-choice tests in assessing academic performance. In addition to the product, however, the process should also be evaluated in Project-Based Learning and must be included in student assessment. It could therefore be suggested that researchers use the progress files and rubrics in evaluating the process in their PBL studies.
8. In conclusion, PBL is found to be 86% more effective in science education than traditional teaching approaches. Therefore, PBL should be frequently used in science education in primary as well as secondary and tertiary education. For this purpose, this finding should be taken into consideration in curriculum development and more PBL activities should be included in course books.

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