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Research Article

Meta-Analysis Covering Studies on Problem-Based Learning

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Abstract

The present study is about meta-analysis conducted to assess the effectiveness of the problem-based learning (PBL) approach. 44 postgraduate and doctoral theses accepted by universities in Turkey in the period 2015 – 2019 were reviewed on national database and out of these studies 25 that were relevant to the problem to be addressed and also had sufficient statistical data were selected for meta-analysis. Of these 25 documents 22 are postgraduate theses and 3 are doctoral dissertations. Analyses shows that the problem-based learning method is positively effective at high level with respect to students cognitive achievement, attitude, skill and retention scores according to the classification made by Cohen et. al.

Key Words

Problem-based learning • Cognitive achievement • Attitude • Skills • Retention

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The need for receiving and shaping knowledge and producing new knowledge brings progressive education philosophy to the fore. This philosophy argues that the individual must be active, not passive, and learning and teaching must be designed as processes of guidance where the learner is at the centre and actively takes part in learning. According to this philosophy, learning and teaching systems must enable the individual to structure knowledge instead of merely memorizing it for acquiring skills that our age requires.

The design of learning and teaching processes in which the individual is active in learning and teaching and able to structure knowledge is quite important. Various methods and techniques can be used in this design. Methods and techniques capable of placing the student to an active position from passive and Cooperative Learning, Brain-Based Learning, Computer Supported Learning and Problem-Based Learning.

As one of the reflections of the constructivist approach as an education theory, the Problem-Based Learning (PBL) is one of the important practices of active learning in the field of education. Unlike conventional teaching methods, the teacher is not a transmitter but undertakes a guiding role. PBL represents experience-based learning which is organized around the inquiry and solution of complex and real life problems and which requires the active participation of individuals in terms of both reasoning and skills.

Problem-based learning may require students to study alone or with their friends a new problem presented them for solution. In this context the student may be asked in education environment to think carefully about the problem and make new suggestions for its solution. The student may be in interaction with other students. This interaction may encourage the tendency to work in cooperation with others. The student may even come up with some original solutions. All these may bring along top level achievements in cognitive, affective and motional areas (Gijbels, Dochy, Van den Bossche, & Segers, 2005).

It may be necessary for teachers to follow six steps which include the following. The first step must determine how the assessment is to be made. This means preparing in advance criteria and tools of measurement to be used in problem solving activities. At the second step the teacher must formulate and bring to education environment a problem that is new and original for students; that will encourage them to think critically and creatively in the process of problem solving. While trying to solve the problem, the student must be able to use such learning activities as brainstorming, problem solving, decision making and project technique. At the third step the teacher must present students their homework and tell when this homework will be assessed. Students may be allowed to read scenarios that are presented to them. The teacher may ask for development of more than one scenario for each problem for each group to discuss and investigate. At the fourth step it must be ensured that students can apply to relevant persons and sources for delineating and identifying the problem. It may be suggested that they apply to experts and go over available sources for this. In this context, students may decide on what they are going to do by discussing among themselves. They must write down their tentative suggestions for the solution of the problem and their hypotheses after having identified the problem. The teacher must ensure that students go through all these steps. At the fifth step students must be asked to present and explain in tables and charts data, products and outcomes that they have reached in relation to hypotheses they tested. At the sixth step the teacher evaluates the performance of individual students or groups. Considerations on outcomes and the process must be a part of this evaluation and the student must be included in the process (Ertmer & Simons, 2006; Onyon, 2012).

Problem-based learning (PBL) is a learning method in which students are first confronted with a problem and then starting of a student-centred research process (Boud- Feletti, 1997; Holen, Manandhar, Pant, Karmacharya, Olson, Koju, & Mansur, 2015; Neufeld & Barrows, 1974; Schmidt, 1993). The objective here is not to solve a single problem but the emergence of new learning objectives through that problem and imparting in students questioning, inquiry, discussion and communication skills while trying to solve the problem (Taşkesenligil, Şenocak & Sözbilir, 2008).

Problem-based learning refers to a learning environment where problems guide learning. In other words it starts with a problem, a problem to be solved and before solving it students are supposed acquire new information. Instead of seeking a single correct answer, students construe the problem, collect relevant information, identify possible solutions and reach to a conclusion (Roh, 2003). Problem-based learning is an educative and (in relation to the programme) student-centred approach mobilizing students for research on an identified problem, combining theory and practice, and applying their knowledge and skills to develop an applicable solution (Savery, 2006). Students are made to meet a real problem for them to solve. They take all steps in identifying the relevant database for their hypotheses. The teacher employs facilitating methods or engages in coaching that directly set students' preliminary information into motion. The self-learning process is completed, and students are asked to evaluate information sources they have used. They are then asked to return to the original problem to reach a broader understanding of what they have learned through self-orientation and to see what other solutions may work better than theirs. While doing these, students are also asked to evaluate their preliminary information and reasoning. Following this second round of problem analysis and synthesis there may be need for another self-oriented learning round. This process continues until the full solution of the problem (Uden, 2006).

PBL was first used in the field of medicine, at the Case W. University Medical School in the US during the 50'ies and then adopted by the Mc Master University, Canada, in the 60'ies. It draws is roots from the principle of learning by doing-living of John Dewey. For inspirational and motivational purposes, students are given real problems from life and the instructor helps students in finding information necessary for the solution of these problems. First applied in the field of health, the PBL approach is used in our day in many fields including law, engineering and education (Demirel, 2005).

Any state that disturbs an individual physically or mentally, brings indecision and points out to more than one way of solution is defined as problem (Karasar, 2004). Dewey defines anything inciting doubt and uncertainty as problem. Since problem denotes a situation that poses difficulty or whose outcome is not known, it becomes important for inviting exploration, discussion or contemplation (Taşkın, 2012).

In PBL which based on problem solving, success largely depends upon students' eagerness and zeal for taking an active part in a cooperative and organized learning environment. Thus, in PBL environments the teacher must help and guide students in noticing and defining the problem, collecting data and reaching a solution.

Evaluation is a process and it is assessed to what extent students could achieve the objectives of the teaching programme. Assessment is not an end by itself but a means in education. In assessing Problem-Based Learning processes there is process assessment using a unique method. In this process, methods such as follow up tests and quizzes can be used to explore the learning difficulties that students face and make necessary corrections and

to provide constant feedback to the programme. In PBL, this assessment of the learning of learners is not conditioned to the final learning outcome. In this approach, the teacher organizes the assessment in a way meaningful to students in order to motivate them to learning.

Objective of the Study

The present study was conducted to apply meta-analysis to 75 outcomes related to 25 studies so far made on problem-based learning and to reach a conclusion about the effectiveness of suggested problem-based learning model. In case the analysis proves that the model suggested is effective the model may be used in eliminating some difficulties confronted in the field of teaching and it may also encourage diverse studies on problem-based learning.

Problem Statement

Does the meta-analysis of studies applying and not applying the method of problem-based learning point to significant difference with respect to students' cognitive achievement, attitude, retention and skills?

Sub-Problems

1. Does the meta-analysis of studies applying and not applying the method of problem-based learning point to significant difference with respect to students' cognitive achievement?

2. Does the meta-analysis of studies applying and not applying the method of problem-based learning point to significant difference with respect to attitude scores of students?

3. Does the meta-analysis of studies applying and not applying the method of problem-based learning point to significant difference with respect to skill scores of students?

4. Does the meta-analysis of studies applying and not applying the method of problem-based learning point to significant difference with respect to retention scores of students?

Literature Survey

Examining some recent studies on problem based learning that can be found in domestic and foreign literature we find that this method has its significant impact on student achievement. Shown studies in this field: Vernon and Blake (1993) conducted meta-analysis on problem-based learning and found that the level of success of problem-based learning group is significantly higher than that of conventional learning group. Outcomes obtained are also supported by data from measurements of students' faculty attitudes, student mod, attendance to courses, academic process variables and humanism. Gijbels et al. (2005) carried out meta-analysis work. In relation to grasping of principles and concepts as well as their interrelations, the average academic achievement scores of the problem-based learning group were significantly higher than the other group. It can be said that problem-based learning is significantly effective in achieving these goals. Çetin (2011) sought to determine the effect of the application of problem-based learning method in primary school life skills course on students' learning outcomes. According to results obtained from the study, achievement test and outcome file assessment scores indicate that problem-based learning method in Life Skills course contributed to the academic success of students. Moralar (2012) investigated the effects of problem-based learning approach in teaching of Science and Technology course on students' academic performance and attitude and motivation towards the course. The study revealed that problem-based learning approach is more effective than conventional approach with respect

to academic achievement and attitude and motivation towards the science and technology course. In their study Çınar and İlik (2013) sought to examine the effect of problem-based learning approach in primary education sciences teaching on students' skills in high-level thinking. The study showed that problem-based learning approach improved student performance. Dağyar (2014) applied meta-analysis to studies conducted to explore the effect of problem-based learning method on academic performance of students. It is found that the size of effect of problem-based learning method on academic performance of students is at medium level with the value 0.62.

The meta-analysis study by Zhang, (2014) on nurse training found the group to which problem-based learning is applied as significantly different than the group with conventional learning in questions related to kidney deficiency. As to average score in responses to questions about diabetes mellitus, on the other hand, achievement scores of the conventional method were considerably higher than that of the problem-based learning group. In the study by Ayaz (2015) the effect of problem-based learning approach on academic achievement and attitude towards science courses of students is analysed by using meta-analysis method. The study found the effect of problem-based learning approach on students' academic performance "strong" with 1.162 while the effect on attitude towards science courses was found "medium" with 0.711.

The study by Karaalioğlu (2016) seeks to explore the effect on achievement and retention of teaching 7th grade level proportion and proportionality through problem-based learning approach. At the end, no significant difference could be found between experimental and control group students with respect to academic achievement and retention. Nevertheless it is concluded from student opinions that they can work with problem-based learning method, that mathematics is learnable by scenarios, that group work is possible, and that students can learn how to respect different opinions and discuss various views. It means that students' opinion on problem-based learning process is positive. Yıldız (2017) investigates PBL's effect on students' academic achievement in the issue "Granular Structure of Matter", attitude towards sciences course and motivations to this course. The study found significant difference in favour of the experimental group vs. control group in students' academic achievement, course attitudes and motivation for success. Söyleyici (2018) sought to investigate the effect of problem-based learning method on scientific process skills, academic performance in relation to grade 7 Light Unit and concept knowledge of primary school 7th grade students. Outcomes of the study show that problem-based learning method has its positive effect on scientific process skills, academic performance and concept knowledge. Öztürk (2019) sought to investigate the effect of problem-based learning method on academic performance and scientific process skills of 7th grade students in the unit "Force and Energy". The study found difference in favour of the experimental group vs. control group in students' academic achievement level.

Methodology

The descriptive method of quantitative survey was used in this study. On the subject of Problem-Based Learning, there are in total forty four theses, eleven doctoral and thirty three post-graduate, written in the period 2015 – 2019. The study covered twenty five of these theses, three doctoral and twenty two post-graduate, congruent with the problem, sub-problems and objective of the study. Table 1 below gives the distribution of theses by their years and academic level.

Table 1

Distribution of Studies Included in Meta-Analysis by Years and Types

Year	Postgraduate Thesis	Doctoral Dissertation	Total
2015	3	1	4
2016	2	0	2
2017	3	1	4
2018	6	0	6
2019	8	1	9
Total	22	3	25

From these 25 theses, 75 outcomes were obtained in relation to scores in cognitive achievement, attitude, skills and retention. Then, general effect was calculated on the basis of fixed effect model of meta-analysis used for continuous data. As a first step in this process, standardized and bias-corrected mean difference (Hedge's g) was calculated. Data collected are related to cognitive achievement, attitude, retention and skills scores. Meta-analysis is a method used in statistically analysing multiple studies and reaching a general conclusion (Sönmez & Alacapınar, 2014).

Data Collection Process

Studies covered in analysis consist of post-graduate and doctoral published and unpublished theses on "Problem-Based Learning Approach" prepared in Turkey in the period 2015–2019 which have their research problem and required statistical data. The surveying of postgraduate theses asserted in Turkey was conducted on the internet site of YÖK (The Council Of Higher Education) National Thesis Centre in Turkish language. This survey yielded the list of academic theses that included "problem temelli öğrenme" in Turkish which means "problem-based learning" in their titles and key words. 44 such theses were found in the survey. After examining these studies, 25 academic theses, 3 doctoral and 22 postgraduate, that satisfied the research problem and inclusion criteria were selected and included in the study. Since the study covered 25 theses on Problem-Based Learning as the subject of meta-analysis there was no need for universe and sample determination.

Data Analysis

Data were examined with the Treatment Effectiveness Meta-Analysis method. It is appropriate to use this technique of analysis when testing whether there is significant difference between cognitive achievement, attitude, skills and retention scores of groups using and not using problem-based learning, but data could not be collected at the same scale. For this, data obtained must be first transformed into a common measure. This is called effect size. In this study "Hedge's g" was used in calculating effect size and confidence interval is taken as 95%. Outcomes are construed according to effect size classification of Cohen, Manion, & Morrison (2007).

Findings

Below are some comments on findings obtained from the analysis of data.

Findings Related to the First Sub-Problem

The first sub-problem of the study is whether there is significant difference in students' cognitive achievements according to the meta-analysis of studies in which problem-based learning is applied or not applied. Homogenous distribution values, average effect sizes and confidence intervals of 32 outcomes in total

related to the effect of problem-based learning on scientific achievement in 25 academic theses covered by meta-analysis are given below in Table 2.

Table 2

Homogeneous and Heterogeneous Distribution Values, Average Effect Sizes and Confidence Intervals of Studies Covered by Meta-Analysis on Cognitive Achievements of Students in Problem-Based Learning with Respect to Effect Models

Model Type	Average effect size (ES)	Degree of freedom (df)	Homogeneity value (Q)	Chi square table value	Standard error (SE)	I^2	95% Confidence interval for effect size	
							Lower Limit	Upper Limit
Fixed Effects Model	0.821	31	407.413	43.7729	0.051	92.391	0.722	0.920
Random Effects Model	1.223	31	407.413	43.7729	0.186		0.859	1.586

In cases where problem-based learning is used in teaching environments, the effect of this approach to student achievement can be said to be positive with the effect size value of 0.821 in the fixed effects model. Homogeneity test yields statistical value Q as 407.413. In chi-square table, the critical value is considered as 43.7729 at significance level of 95% and with degree of freedom of 31. Since 407.413, the statistical value Q calculated in this study is greater than 43.7729 as critical value, it can be said that the distribution of effect sizes has a **heterogeneous** nature. Indeed, having 92.391 as calculated I^2 may be accepted as showing that effect size at heterogeneous level is high (Cooper, 2010).

Since the distribution in the study has heterogeneous character, it was sought to avoid illusions deriving from this heterogeneous character of the sample by conducting analyses in line with random effects model (Yıldız, 2002). On this basis, the effectiveness of teaching with or without using problem-based learning approach is assessed according to random effects model. Meta-analysis of 32 data according to random effects model gives the effect size as ES= 1.223 with standard error of 0.186 in 95% confidence interval with upper and lower limits as 1.586 and 0.859, respectively. It can be said that effect size value is in the category "large" according to Cohen's (2007) classification, which suggests that the use of problem-based learning in class practices have its positive effect on academic performance. These suggest that average success scores in groups engaged in problem-based learning are significantly higher than other groups without problem-based learning. It can be argued that problem-based learning significantly affects achievements at this level. Findings related to effect size of studies are given in Table 3 and Figure 1.

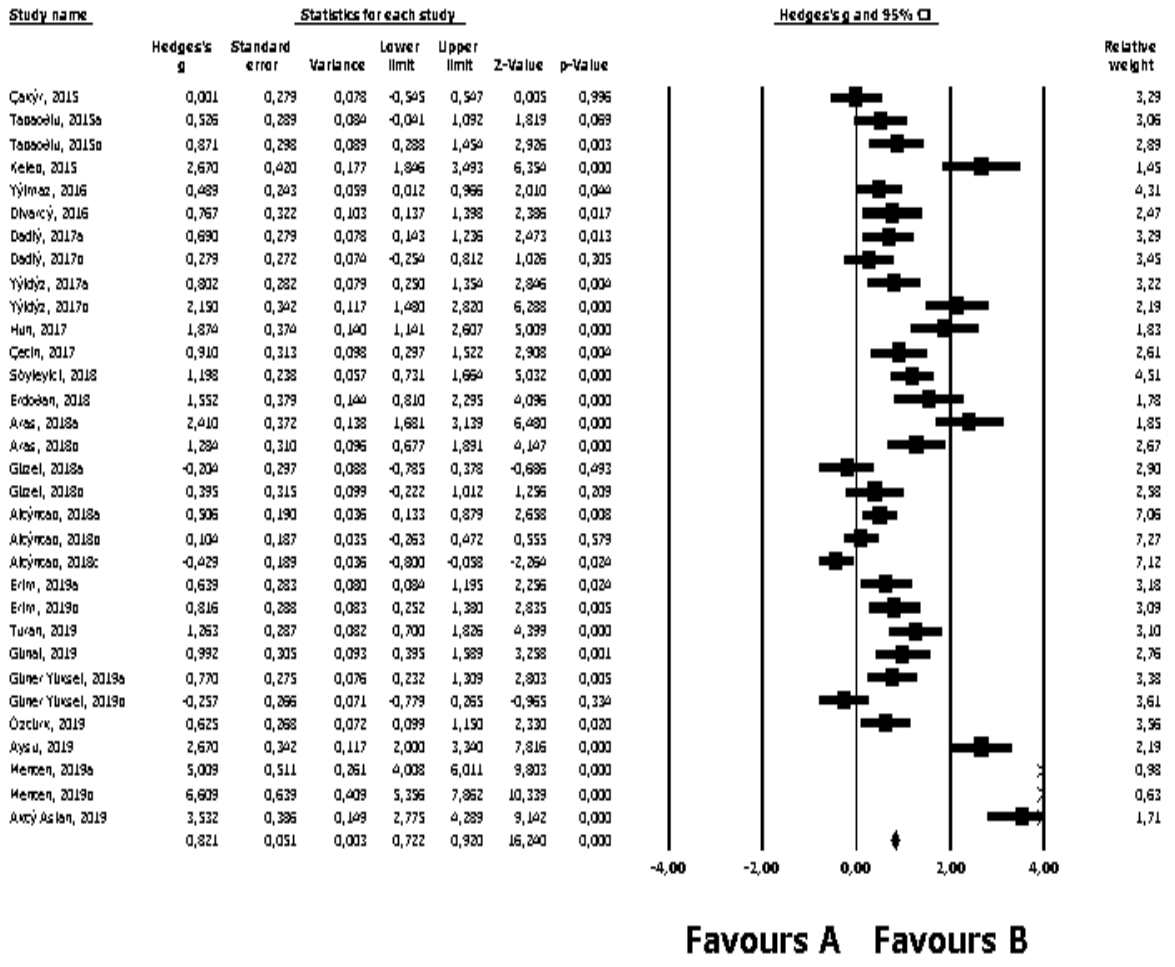
Table 3

Distribution of Effect Sizes in Studies Covered by Meta-Analysis on Cognitive Achievements of Students in Problem-Based Learning According to the Classification Made by Cohen et. al.

Effect Size Level	Frequency	Percentage
Small	6	18,750
Medium	9	28,125
Large	18	53,125
Total	32	100

Examining Table 3, we found that, according to Cohen et. al. (2007) the effect sizes of small and medium levels with 18 studies are equal (7).

Figure 1. Effect size values related to cognitive achievement



Meta Analysis

In Figure 1 lines on both sides of squares show the lower and upper limits of effect sizes in 95% confidence interval while the rhomb shows the overall effect size of studies. Taking a look we see 0.001 as the smallest and 6.609 as the widest effect size.

Findings Related to the Second Sub-Problem

The second sub-problem of the study is whether there is significant difference in students' attitude scores according to the meta-analysis of studies in which problem-based learning is applied or not applied. Homogenous distribution values, average effect sizes and confidence intervals of 24 outcomes in total related to the effect of problem-based learning on attitude scores in 25 academic theses covered by meta-analysis are given below in Table 4.

Table 4

Homogeneous and Heterogeneous Distribution Values, Average Effect Sizes and Confidence Intervals of Studies Covered by Meta-Analysis on Attitude Scores *of Students in Problem-Based Learning with Respect to Effect Models*

Model Type	Avarage effect size (ES)	Degree of freedom (df)	Homogeneity value (Q)	Chi Square table value	Standart error (SE)	I^2	%95 Confidence interval for effect size	
							Lower limit	Upper limit
Fixed Effects Model	0,914	23	446,546	35,1725	0,065	94,849	0,785	1,042
Random Effects Model	1,732	23	446,546	35,1725	0,294		1,156	2,308

In cases where problem-based learning is used in teaching environments, the effect of this approach to student attitude scores can be said to be positive with the effect size value of 0.914 in the fixed effects model. Homogeneity test yields statistical value Q as 446,546. In chi-square table, the critical value is considered as 35,1725 at significance level of 95% and with degree of freedom of 23. Since 446,546, the statistical value Q calculated in this study is greater than 35,1725 as critical value, it can be said that the distribution of effect sizes has a heterogeneous nature. Indeed, having 94,849 as calculated I^2 may be accepted as showing that effect size at heterogeneous level is high (Cooper, 2010).

Since the distribution in the study has heterogeneous character, it was sought to avoid illusions deriving from this heterogeneous character of the sample by conducting analyses in line with random effects model (Yıldız, 2002). On this basis, the effectiveness of teaching with or without using problem-based learning approach is assessed according to random effects model. Meta-analysis of 24 data according to random effects model gives the effect size as ES= 1,732 with standard error of 0.294 in 95% confidence interval with upper and lower limits as 2,308 and 1,156, respectively. It can be said that effect size value is in the category "large" according to Cohen's (2007) classification, which suggests that the use of problem-based learning in class practices have its positive effect on attitude scores. These suggest that average attitude scores in groups engaged in problem-based learning are significantly higher than other groups without problem-based learning. It can be argued that problem-based learning significantly affects attitude scores at this level. Findings related to effect size of studies are given in Table 5 and Figure 2.

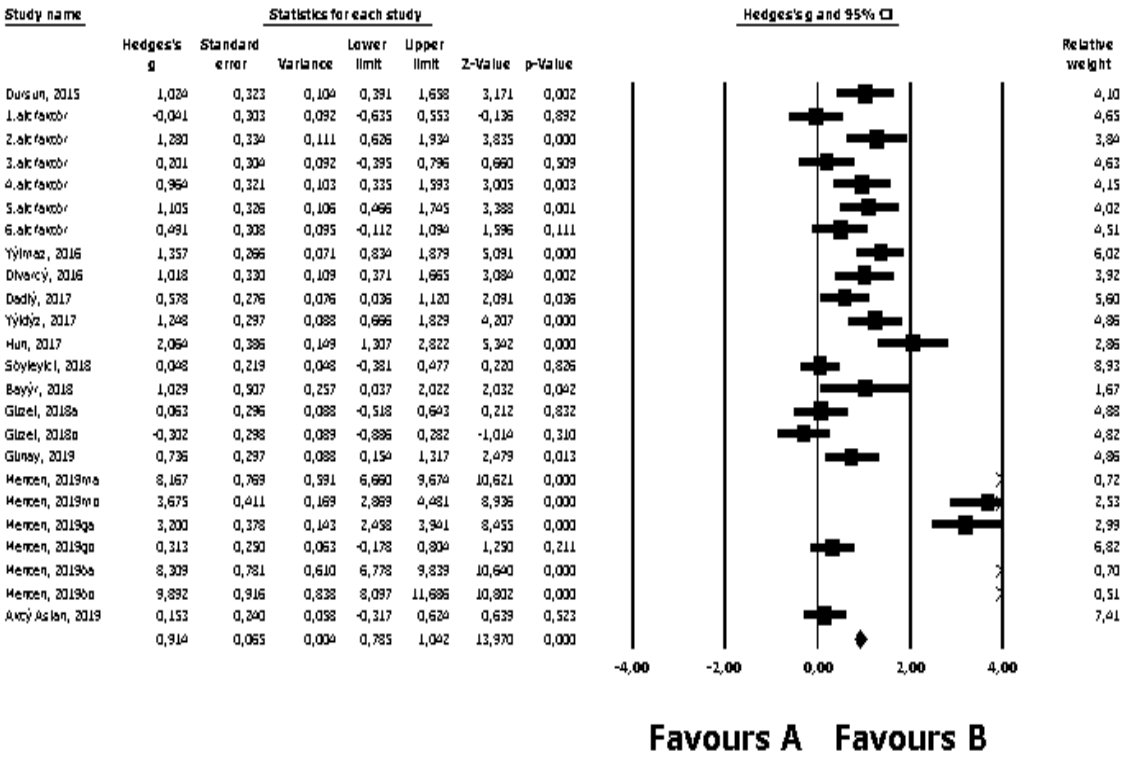
Table 5

Distribution of Effect Sizes in Studies Covered by Meta-Analysis on Attitude Scores of Students in Problem-Based Learning According to the Classification Made by Cohen et. al.

Effect size level	Frequency	Percentage
Small	7	29,167
Medium	3	12,500
Large	14	58,333
Total	24	100

When table 5 is examined, it is seen that according to Cohen et al., 14 studies have a large effect size.

Figure 2. Effect size values related to attitude scores



In Figure 2 lines on both sides of squares show the lower and upper limits of effect sizes in 95% confidence interval while the rhomb shows the overall effect size of studies. Taking a look we see 0.041 as the smallest and 9.892 as the widest effect size.

Findings Related to the Third Sub-Problem

The third sub-problem of the study is whether there is significant difference in students' skill scores according to the meta-analysis of studies in which problem-based learning is applied or not applied. Homogenous distribution values, average effect sizes and confidence intervals of 10 outcomes in total related to the effect of problem-based learning on skill scores in 25 academic theses covered by meta-analysis are given below in Table 6.

Table 6

Homogeneous and Heterogeneous Distribution Values, Average Effect Sizes and Confidence Intervals of Studies Covered by Meta-Analysis on Skill Scores of Students in Problem-Based Learning with Respect to Effect Models

Model Type	Avarage effecet size (ES)	Degree of freedom (df)	Homogeneity value (Q)	Chi Square table value	Standard error (SE)	I^2	%95 Confidence interval for effect size	
							Lower limit	Upper limit
Fixed Effects Model	0,841	9	102,701	16,9190	0,091	91,237	0,663	1,019
Random Effects Model	0,838	9	102,701	16,9190	0,308		0,234	1,442

In cases where problem-based learning is used in teaching environments, the effect of this approach to student skill scores can be said to be positive with the effect size value of 0.841 in the fixed effects model. Homogeneity test yields statistical value Q as 102,701. In chi-square table, the critical value is considered as 16,9190 at significance level of 95% and with degree of freedom of 9. Since 102,701, the statistical value Q calculated in this study is greater than 16,9190 as critical value, it can be said that the distribution of effect sizes has a heterogeneous nature. Indeed, having 91,237 as calculated I^2 may be accepted as showing that effect size at heterogeneous level is high (Cooper, 2010).

Since the distribution in the study has heterogeneous character, it was sought to avoid illusions deriving from this heterogeneous character of the sample by conducting analyses in line with random effects model (Yıldız, 2002). On this basis, the effectiveness of teaching with or without using problem-based learning approach is assessed according to random effects model. Meta-analysis of 10 data according to random effects model gives the effect size as ES= 0,838 with standard error of 0.308 in 95% confidence interval with upper and lower limits as 1.442 and 0.234, respectively. It can be said that effect size value is in the category "large" according to Cohen's classification (2007), which suggests that the use of problem-based learning in class practices have its positive effect on skill scores. These suggest that average skill scores in groups engaged in problem-based learning are significantly higher than other groups without problem-based learning. It can be argued that problem-based learning significantly affects skill scores at this level. Findings related to effect size of studies are given in Table 7 and Figure 3.

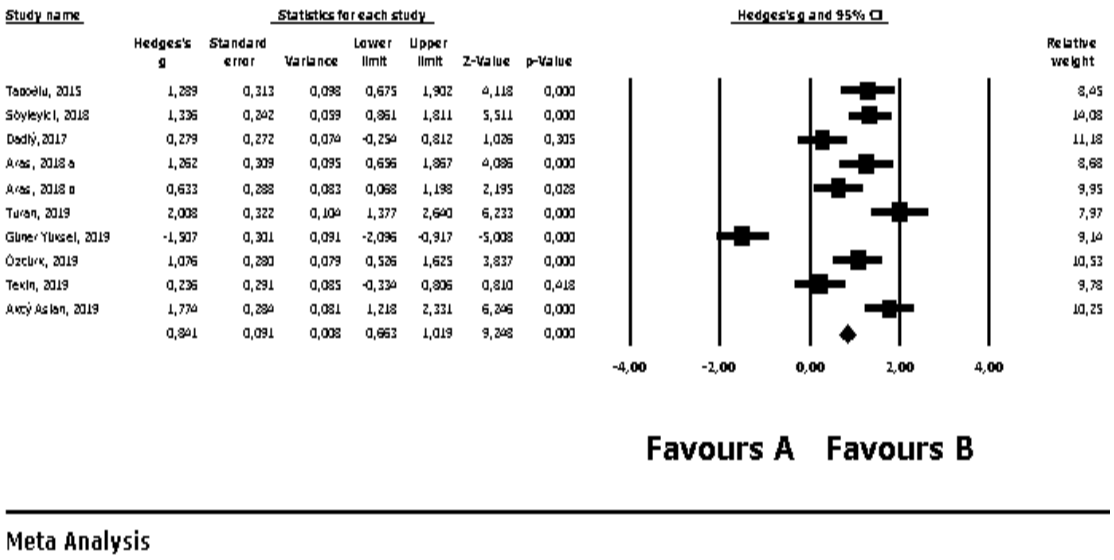
Table 7

Distribution of Effect Sizes in Studies Covered by Meta-Analysis on Skill Scores of Students in Problem-Based Learning According to the Classification Made by Cohen et. al.

Effect Size Model	Frequency	Percentage
Small	2	20
Medium	1	10
Large	7	70
Total	10	100

Examining Table 7, it can be seen that, according to Cohen et al., 6 studies have a large effect size.

Figure 3. Effect Size Values Related to Skill Scores



In Figure 3 lines on both sides of squares show the lower and upper limits of effect sizes in 95% confidence interval while the rhomb shows the overall effect size of studies. Taking a look we see 0.236 as the smallest and 2.008 as the widest effect size.

Findings Related to the Fourth Sub-Problem

The fourth sub-problem of the study is whether there is significant difference in students' retention scores according to the meta-analysis of studies in which problem-based learning is applied or not applied. Homogenous distribution values, average effect sizes and confidence intervals of 9 outcomes in total related to the effect of problem-based learning on retention scores in 25 academic theses covered by meta-analysis are given below in Table 8.

Table 8

Homogeneous and Heterogeneous Distribution Values, Average Effect Sizes and Confidence Intervals of Studies Covered by Meta-Analysis on Retention Scores of Students in Problem-Based Learning with Respect to Effect Models

Model Type	Avarage effect size (ES)	Degree of freedom (df)	Homogeneity value (Q)	Chi Square table value	Standard error (SE)	I^2	%95 Confidence interval for effect size	
							Lower limit	Upper limit
Fixed Effects Model	1,487	8	219,184	15,5073	0,119	96,35	1,254	1,720
Random Effects Model	2,932	8	219,184	15,5073	0,642		1,674	4,191

In cases where problem-based learning is used in teaching environments, the effect of this approach to student retention scores can be said to be positive with the effect size value of 1.487 in the fixed effects model. Homogeneity test yields statistical value Q as 219.184. In chi-square table, the critical value is considered as

15.5073 at significance level of 95% and with degree of freedom of 8. Since 219.184, the statistical value Q calculated in this study is greater than 15.5073 as critical value, it can be said that the distribution of effect sizes has a heterogeneous nature. Indeed, having 96.35 as calculated I^2 may be accepted as showing that effect size at heterogeneous level is high (Cooper, 2010).

Since the distribution in the study has heterogeneous character, it was sought to avoid illusions deriving from this heterogeneous character of the sample by conducting analyses in line with random effects model (Yıldız, 2002). On this basis, the effectiveness of teaching with or without using problem-based learning approach is assessed according to random effects model. Meta-analysis of 9 data according to random effects model gives the effect size as ES= 2.932 with standard error of 0.642 in 95% confidence interval with upper and lower limits as 4.191 and 1.694, respectively. It can be said that effect size value is in the category "large" according to Cohen's classification (2007), which suggests that the use of problem-based learning in class practices have its positive effect on retention scores. It can be argued that problem-based learning significantly affects retention scores at this level. Findings related to effect size of studies are given in Table 9 and Figure 4.

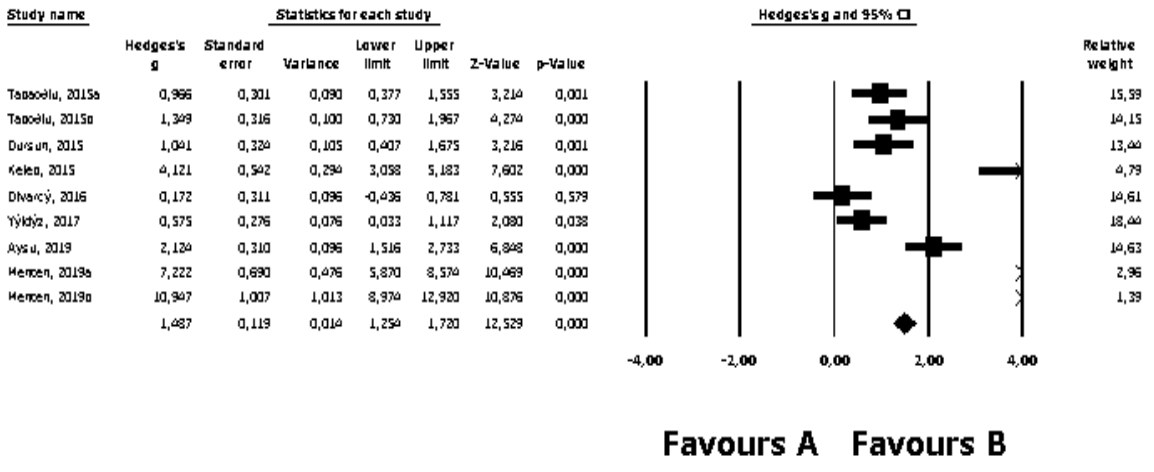
Table 9

Distribution of Effect Sizes in Studies Covered by Meta-Analysis on Retention Scores of Students in Problem-Based Learning According to the Classification Made by Cohen et. al.

Effect size level	Frequency	Percentage
Small	1	11,111
Medium	1	11,111
Large	7	77,778
Total	9	100

Analysing Table 9, it can be seen that according to Cohen et al., studies with small and medium effects have an equal number (1) and more than half of the studies have a large effect size.

Figure 4. Effect Size Values Related to Retention Scores



In Figure 4 lines on both sides of squares show the lower and upper limits of effect sizes in 95% confidence interval while the rhomb shows the overall effect size of studies. Taking a look we see 0.121 as the smallest and 10.947 as the widest effect size.

Discussion

The outcomes of problem-based meta-analysis are examined under 4 headings in this study. According to meta-analysis of cases where problem-based learning is applied and not applied, a significant difference is found in favour of problem-based learning in each of four sub-problems, scares of students in cognitive achievement, attitude, skills and retention. Where this difference derives from is tried to be explained on the basis of studies about what problem-based learning is.

Problem-based learning may require the student to take following steps in solving problems that are confronted with. These steps are as follows: Defining and delimiting the problem; establishing hypotheses (identifying possible suggestions for solution); collecting data that is related to the problem (determining what is given in the problem); conducting relevant operations (collecting relevant data, writing the appropriate formula for solution, analysing data by going through mathematical and statistical operations); testing hypotheses (verification, falsification, filling gaps, setting new hypotheses); reaching conclusion, confirmation, presenting as a report). In this process the student is expected to do all these either alone or as group with friends. Student's active participation to learning process may significantly affect learning, skills ad attitude. As a matter of fact, studies conducted on this point found significant relationship from 0.50 to 0.90 between student's doing things and teaching what he has learnt to others and his achievement.

Problem-based learning also contains scientific method. Steps mentioned above can be taken also as steps of scientific method. Organizing and maintaining learning activities through scientific method may affect student's critical thinking skills and creativity. Indeed, in this process the person concerned may acquire skills to solve not only singular and similar problems but others that are different and confronted in life (Hmelo-Silver, 2004).

While in the process of scientific research, the student may use both inductive and deductive methods together. This way of reasoning may be called hypothetic-deductive process. Or the student may use deduction first and then induction which helps him to improve his reasoning; how to think and think in a critical way replaces what to think. What is really important in problem-based learning is finding how to solve any problem confronted by using reasoning, implementing the solution reached and learning how to work in teams (Thomas, 2010).

Active participation, reasoning, critical and original thinking may affect student's attitude towards learning. Successes in this process may fuel the desire of the person to solve problems. Indeed, studies confirm that there is positive correlation between success and attitude. According to Bloom's learning model, affective entry characteristics of the student is one of the variables affecting success (Bloom, 1976). Studies find significant correlation of 0.25 between affective entry characteristics and success (Alacapınar, 2012).

In problem-based learning, taking active part in education environment, the student may feel obliged to acquire knowledge and skills necessary fir the solution of the problem. He can correct his mistakes and fill his gaps this way. The level of knowledge starting with grasping and practising may then move to steps of analysis, synthesis and assessment. Building of knowledge and skills in a cumulative way may further trigger and sustain

the desire for further learning and problem solving. There is a correlation of 0.50 between student's cognitive preparedness and learning. Taking cognitive entry status and affective entry characteristics together 0.70 of learning can be explained. In problem solving environments, student's cognitive and affective characteristics may ensure the retention of what has been learned through active participation (Bloom, 1976). According to studies, retention, in other words keeping in mind what has been learned largely depends upon student's deeds and teaching others, which are dominant characteristics in problem-based learning. Indeed, identifying and delimiting the problem, setting hypothesis, collecting and analysing data, rejecting or confirming hypotheses, reporting and presenting, etc. are all deeds which mean learning through doing and experiencing which makes it more difficult to forget what has been learned (Yew & Goh, 2016). This can be considered as a variable affecting retention. It can also be said that all stages in problem-based learning affect students' learning outputs.

Problem-based learning activities may comprise problem solving, experimentation, observation and project development, critical and creative thinking, cooperative learning and life-long learning (Hmelo-Silver & Barrows, 2006). Depending on the nature of the problem these learning-teaching activities may be used in problem-based learning. As to which method and technique is to be used in problem-based learning, this may depend upon student's choice and the state of the problem (Sönmez, 1999). There may be researches covering all previously conducted meta-analyses. Since meta-analyses provide evidence that problem-based learning is indeed effective, teachers and students can be encouraged to use this process of learning effectively in their education environments. Both teachers and students may be offered applied training in this.

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