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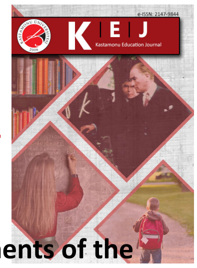

| Research Article / Araştırma Makalesi |

The Effect of Student-Centered Teaching Methods in Science Laboratories on Academic Achievements of the Students: A Meta-Analysis Study

Fen Laboratuvarlarında Öğrenci Merkezli Öğretim Yöntemlerinin Öğrencilerin Akademik Başarılarına Etkisi: Bir Meta-Analiz Çalışması

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Keywords

1.Laboratory-based science education
2.Meta-analysis
3.Academic achievement
4.Effect-size

Anahtar Kelimeler

1.Laboratuvar destekli fen eğitimi
2.Meta-analiz
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Abstract

Purpose: In this study, it is aimed to synthesize the results obtained from the experimental studies investigating the effect of laboratory-based science education practices on academic achievements of the students in Turkey via meta-analysis method.

Design/Methodology/Approach: In the study is used meta-analysis method. Articles, master's theses and doctoral dissertations having the statistical data that can be included in the meta-analysis study and appropriate to the research problem as a result of the related literature review made on the studies conducted in Turkey between 2013-2018 were analyzed by reviewing in Turkish and English languages from the national and international databases. As a result of the literature review, a total of 34 studies concerning the effect of student-centered teaching methods in science laboratories on academic achievements of the students in laboratory courses and including appropriate data for the coding protocol were included in the meta-analysis. In these individual studies with totally 2171 participants; moderator analyses were performed for the variables of educational level, publication types, teaching methods, science areas and application regions; whereas, meta-regression analyses were performed for the variables of sample size and application durations.

Findings: It was determined that all the studies included in the study had a positive effect size value. A heterogeneous distribution was determined in the studies included ($Q=79.41$ $p<0.05$, $I^2=58.44$). Overall effect size value of student-centered teaching methods concerning academic achievements of the students in laboratory courses was found to be $d=0.94$ (95% CI, SE=0.07) at the confidence interval of 0.80 and 1.09 using random effects model.

Highlights: It was determined that laboratory-based learning approach affected academic achievements of the students moderately. As a result of the moderator analyses, it was found that the effect sizes did not vary according to the variables of educational level, teaching methods, publication types, science areas, and application regions.

Öz

Çalışmanın amacı: Bu araştırmada, Türkiye'de laboratuvara dayalı fen öğretimi uygulamalarının öğrencilerin akademik başarıları üzerindeki etkisini inceleyen deneysel çalışmalardan elde edilen bulguların meta-analiz yöntemiyle sentezlenmesi amaçlanmaktadır.

Materyal ve Yöntem: Bu çalışmada meta-analiz yöntemi kullanılmıştır. Bunun için 2013-2018 yılları arasında Türkiye'de yapılmış çalışmalarla ilgili literatür taraması sonucunda araştırma problemine uygun ve meta-analiz çalışmasına dahil edilebilecek istatistiksel verilere sahip makaleler, yüksek lisans ve doktora tezleri ulusal ve uluslararası veri tabanlarından Türkçe ve İngilizce dillerinde taranarak incelenmiştir. Literatür taraması sonucunda fen laboratuvarlarında öğrenci merkezli öğretim yöntemlerinin öğrencilerin laboratuvar derslerinde olan akademik başarıları üzerine etkisine ilişkin ve kodlama protokolüne uygun verileri içeren toplam 34 çalışma meta-analize dâhil edilmiştir. Toplam katılımcı sayısının 2171 olduğu bu bireysel çalışmalarda; öğrenim düzeyi, yayın türleri, öğretim yöntemleri, fen bilimi alanları ve uygulama bölgeleri türlerinde moderatör analizi, örneklem büyüklüğü ve uygulama süreleri değişkenleri için de meta-regresyon analizi yapılmıştır.

Bulgular: Araştırmaya dâhil edilen çalışmaların tamamının pozitif etki büyüklüğü değerine sahip oldukları belirlenmiştir. Dâhil edilen çalışmalarda heterojen bir dağılım belirlenmiştir ($Q=79.41$ $p<.05$, $I^2=58.44$). Öğrenci merkezli öğretim yöntemlerinin öğrencilerin laboratuvar derslerine yönelik akademik başarılarına ilişkin genel etki büyüklüğü değeri rastgele etkiler modeli kullanılarak 0.80 ile 1.09 güven aralığında $d=0.94$ (%95 CI, SE=0.07) olarak belirlenmiştir.

Önemli Vurgular: Laboratuvara dayalı öğrenme yaklaşımının, öğrencilerin akademik başarılarını orta düzeyde etkilediği belirlenmiştir. Yapılan moderatör analizleri sonucunda etki büyüklüklerinin; öğrenim düzeyleri, öğretim yöntemleri, yayın türleri, fen bilimi alanları ve uygulama bölgeleri değişkenlerine göre farklılaşmadığı sonucuna varılmıştır. Ayrıca örneklem büyüklüğü ve uygulama sürelerinin etki büyüklükleri ile ilişkisini belirlemek için yapılan meta-regresyon analizleri sonucunda etki büyüklükleri ile uygulama süreleri arasında anlamlı bir sonuç bulunmazken; etki büyüklükleri ile örneklem büyüklüğü arasında negatif yönde anlamlı bir ilişki olduğu bulunmuştur.

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INTRODUCTION

The roles of teachers and students in the education system have changed with the continuous increase of information today. While the teacher who is in the position of transmitting the information is now a guide for the students to reach the information, the students are the ones who are examining, questioning and wondering and they are at the center of learning. The teaching strategies built on constructivism form significant developments by encouraging the students and promoting cognitive conflict. This situation in the learning process enables the formation of information transferred from a teacher through active configurations rather than passive acquisition (Franklin, 2012). Effective and efficient science teaching is possible in the teaching environments where scientific knowledge in science is revealed. Today, constructivism principles guide the curricula of the science courses and the laboratory studies are one of the active learning activities that are appropriate to the student-centered strategies that can enable structuralist learning-teaching approach (Ketpichainarong, Panijpan & Ruenwongsa, 2010). During the laboratory applications suitable for the constructivist approach, students reach the information by finding their own solutions and perform more meaningful and permanent learning by associating the information they gained with the existing information (Çallıca, Erol, Sezgin & Kavcar, 2000). In science programs prepared by Ministry of National Education (MEB), it is aimed to teach new skills such as entrepreneurship and engineering skills as well as scientific process skills in the science laboratory in the Curriculum of Science Course by giving special importance in the basis of purpose to the laboratory usage (MEB, 2018). The use of laboratory in science courses plays an important role for students not only to gain scientific process skills like making observation, classification and measurement, but also to gain causal process skills such as making estimation, inferences or to gain experimental skills like forming hypothesis and determining variables (Aydoğdu & Kesercioğlu, 2005; Benzer & Muşlu Kaygısız, 2017; Toprak, 2011).

The science educators have stated that learning through the laboratory activities would be more qualified and that the science subjects could not be learned fully without experimenting (Çepni & Ayvacı, 2006; Hofstein & Lunetta, 2004). In addition, it is thought that students' inadequacies in theoretical issues can be eliminated by conducting the laboratory course in parallel with the theoretical courses (Kurt, Devecioğlu, & Akdeniz, 2002). Today, some educators have begun to investigate and question the effectiveness of laboratory teaching (Hofstein & Lunetta, 1982). These studies have revealed the importance of research-based (Aydoğdu & Ergin, 2008), questioning-based (Duru, Demir, Önen & Benzer, 2011; Kırıktaş, 2014), cooperation-based (Arslan & Zengin, 2015; Yapıcı, Havedanlı & Oral, 2009; Yılmaz & Karaçöp, 2018), project-based learning (Morgil, Seyhan & Seçken, 2009; Sert Çıbık, İnce Aka & Kayacan, 2016), argumentation-based learning (Demircioğlu & Uçar, 2015; Güler, 2016) and FeTeMM (Science-Technology-Engineering) (Yıldırım & Altun, 2015) based laboratory practices for developing gains in science education such as knowledge, skill, concept teaching and attitudes. The fact that the science course has a content formed with abstract and complex concepts makes it a necessity to use laboratories effectively which have an important place in learning these concepts meaningfully and permanently by these students (Keleş, Kılıç & Uzun, 2015).

As it is seen, although there are numerous studies in Turkey reaching repeated, independent and completely different results about the effect of laboratory-based science education on the academic achievements of the students by using different techniques, a single meta-analysis study was conducted between 2000-2012 concerning this subject (Demirtaş-Yılmaz, 2014). Although the effect of laboratory-based teaching method in science education on the academic achievement was examined in this master's thesis study, it shows differences from the purpose of this study since the number of primary studies is less compared to this study and inter-variable analyses were not performed. Meta-analysis is described in the literature as a method of analysis which converts the results of multiple studies which are independent from each other on a specific subject into a unit of measurement called as effect size (Borenstein, Hedges, Higgins, & Rothstein, 2005).

The Purpose of the Study

The aim of this study is to synthesize the results obtained from the experimental studies, being conducted in Turkey between 2013-2018 and investigating the effect of laboratory-based science teaching practices on the academic achievements of the students compared to the traditional teaching, with meta-analysis method and to reach a clear judgment. For this purpose, the answers for the following questions were sought in the study:

1. How do student-centered teaching methods in science laboratories affect academic achievements of the students, compared to traditional laboratory method?
2. Does the effect of student-centered teaching methods in science laboratories on academic achievements of the students vary according to study characteristics (educational level, publication types, teaching methods, science areas and application regions)?
3. Is there a significant correlation between the effect of student-centered teaching methods in science laboratories on academic achievements of the students and application duration?
4. Is there a significant correlation between the effect of student-centered teaching methods in science laboratories on academic achievements of the students and sample size?

METHOD

This section contains the titles of the research model used in the study, data collection, inclusion and exclusion criteria, data coding and analysis, and selection and interpretation of the statistical model.

Study Model

In this study, the studies investigating the effect of laboratory-based science education on the academic achievements of the students were examined by using the meta-analysis method. Meta-analysis was defined as a quantitative method that synthesizes experimental study results in the form of effect size (Card, 2012).

Data Collection and Literature Review

In this study, the data included in the analysis were obtained from the scientific articles, master's theses, and doctoral dissertations published in peer-reviewed journals investigating the effects of laboratory-based science education on the academic achievements of the students in Turkey. The review was conducted between “September 2018 and November 2018” in “Ulakbim”, “Google Scholar”, “Eric”, “Science Direct” and “Higher Education Council National Thesis Center” databases. The review was conducted in Turkish and English languages by using the keywords of “science/biology/physics/chemistry laboratory activities/applications”, “laboratory-based instruction”, “laboratory approaches”, and “science teaching laboratory”. As a result of the review, 34 studies that could be included in the meta-analysis that contains the data appropriate for the coding protocol and addresses the effect of laboratory-based science teaching on the academic achievements of the students were reached. In these studies, there were 2171 people including 1081 people in the experimental group and 1090 people in the control group.

Figure 1 shows the flow diagram showing how a total of 210 studies were reduced to 34 studies included in the meta-analysis.

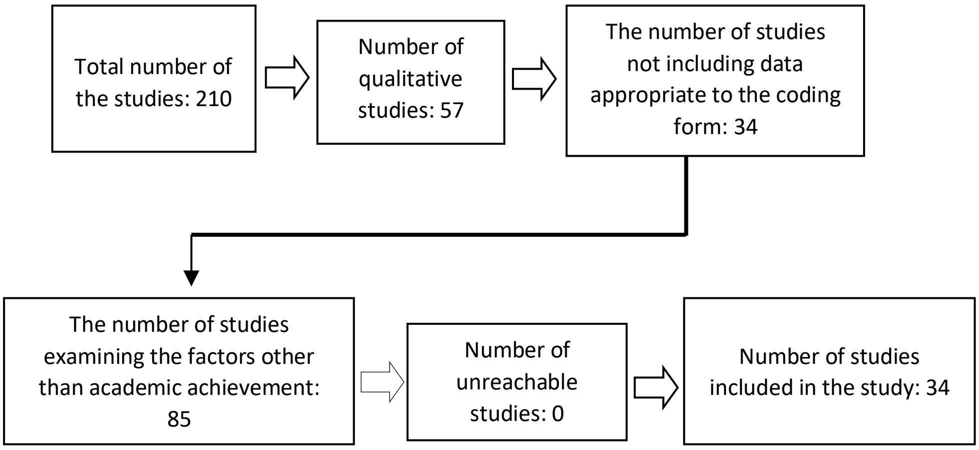

Figure 1. Flow diagram

Inclusion Criteria

The criteria used for the selection of the studies included in the meta-analysis are about being in the limitations of the study and having the statistical data for the analysis (Wolf, 1986). The studies included in this study were conducted according to the following criteria;

1st Criterion: Being conducted in Turkey between 2013-2018.

2nd Criterion: Being published as a master’s thesis, doctoral dissertation or in a national / international peer-reviewed scientific journal.

3rd Criterion: Being an experimental or quasi-experimental study.

4th Criterion: Having applied laboratory applications using student-centered teaching methods to the experimental group and traditional laboratory applications to the control group.

5th Criterion: Having sufficient numerical data (arithmetic mean, standard deviation, sample size, etc.) to calculate the effect size.

Study Exclusion Criteria

In this study, the studies that have only qualitative results, have insufficient numerical data for calculating the effect size, briefly, do not meet the inclusion criteria were excluded from the meta-analysis.

Coding Method

In order to form data by classifying the information of the studies included in the meta-analysis, the coding method was used. In the study, a coding form was prepared to understand whether or not the studies were eligible for the inclusion criteria of the meta-analysis and to conduct a comparison between the studies. Some characteristics in the coding form are as follows: Name and writer of the study, publication type, publication year, educational level, application duration, teaching method, applied science areas, application region and sample size.

Dependent and independent variables

In this meta-analysis study, the effect sizes of the effect of student-centered teaching methods in science laboratories on academic achievements of the students were defined as dependent variables. The independent variables were the study characteristics.

Study characteristics

In the present meta-analysis study, the independent variables obtained from the studies meeting the inclusion criteria as a result of the literature review were recorded in the coding form since they can reveal the differences between the effect sizes. Characteristics of the study were determined as; I) educational level (secondary education, high education, undergraduate education), II) application duration, III) sample size, IV) publication type (articles, theses), V) application region (Aegean, Marmara, Mediterranean, Central Anatolia, Black Sea and Eastern Anatolia), VI) applied laboratory course (science laboratory, physics laboratory, chemistry laboratory, and biology laboratory), and VII) teaching methods.

Data Analysis

In the meta-analysis study, the effect size determining the power and direction of the relationship in a study is calculated (Başol-Göçmen, 2004). In the calculation of the effect size in this study, Cohen's d was used (Cohen, 1988). In the study, effect size classification was used in the comparison of the effect sizes, and the effect sizes and their variations for each study and the comparison of the groups were calculated with Comprehensive Meta-Analysis Version 2.0 (CMA V2) statistical packaged software for meta-analysis (Borenstein et al., 2005). CMA program was used for overall effect sizes, publication bias, moderator analyses, meta-regression analyses and to draw forest plot and funnel plot diagrams. SPSS 17.0 software was used to examine the normality of the effect sizes obtained from the study.

Statistical Model Selection

In meta-analysis studies, researchers use the fixed effects model or random effects model. Researcher or researchers should decide which one of these models will be used. In the fixed effects model, all studies are assumed to have a single common (actual) effect size and the possible differences in the observed effect sizes are stated to be caused by the sampling error. In the random effects model, the actual effect may vary from study to study. Age, educational level, and participant difference cause different effect sizes. Therefore, studies can show heterogeneity (Borenstein, Hedges, Higgins, & Rothstein, 2013). Based on this information, the data analysis in this study was performed under the random effects model since it includes studies in different educational levels and these studies have different intervention practices.

Q statistics are used to measure heterogeneity in meta-analysis studies (Üstün & Eryılmaz, 2014). In addition, I^2 value giving the total variation rate about the effect size also gives information about heterogeneity. Higgins & Thompson (2002) recommended the heterogeneity levels as 25% (low heterogeneous), 50% (moderate heterogeneous), and 75% (high heterogeneous) (cited by Cooper, Hedges, & Valentine, 2009).

Measurement type and interpretation of the effect size

Cohen, Manion, & Morrison's (2011) classifications were used in the interpretation of the effect sizes obtained as a result of meta-analysis. According to Cohen et al. (2011), the effect size classification is as follows:

- 0 ≤ effect size value ≤ 0.20 is weak effect
- 0.21 ≤ effect size value ≤ 0.50 is small effect
- 0.51 ≤ effect size value ≤ 1.00 is medium effect
- 1.01 ≤ effect size value is strong effect.

In the studies included in the meta-analysis, positive effect size values will be interpreted in favor of the experimental group and the negative ones will be interpreted in favor of the control group.

FINDINGS

Table 1 shows the frequency and percentage values of publication years, educational levels, publication types, teaching methods, applied science areas, and application regions of the studies included in the study in this section.

Table 1. Distribution of the data on the examined studies

Variable	Frequency (f)	Percentage (%)		Frequency (f)	Percentage (%)
Publication Year			**Science Areas**		
2013	4	12	Biology Lab.	5	15
2014	7	21	Science Lab.	11	33
2015	7	21	Physics Lab.	9	26
2016	6	18	Chemistry Lab.	9	26
2017	3	9	**Application Regions***		
2018	7	21	Mediterranean	3	9
Educational Level			Eastern Anatolia	3	9
Secondary Education	4	12	Aegean	2	6
High Education	2	6	Southeastern Anatolia	2	6
Undergraduate Education	28	82	Central Anatolia	4	12
Publication Types			Black Sea	13	38
Doctoral Thesis	5	15	Marmara	4	12
Master's Thesis	6	18	Unspecified	3	9
Article	23	67			
Methods Used in the Laboratory**					
Open-Ended Laboratory	3	9			
Argumentation	4	12			
STEM	1	3			
Collaborative	4	12			
Model Using	2	6			
Learning Cycle	5	15			
Project-Based	1	9			
Questioning-Based	3	9			
Technology-Aided	7	21			
Estimation-Observation-Explanation (EOE)	3	9			
Vee Diagram	1	3			

*Methods with a frequency of 1 were not included in the analysis.

**3 studies whose application region was not specified were not included in the analysis.

When examining Table 1; it was seen that there were the variables of publication year, educational level, publication type, teaching method, applied science area, and application regions. According to the table, majority of the studies were conducted in 2014, 2015, and 2018 (21%), at the level of undergraduate education (82%), published as articles (67%), using technology-aided teaching method (21%), in the area of science laboratory (33%) and in the Black Sea Region (38%).

Publication Bias Results

Publication bias is a case occurring as a result of including only the articles, which are published and have significant results, in the meta-analysis and excluding the studies, which have no significant results and are not published, from the meta-analysis (Şen & Akbaş, 2016). In this study, three methods as funnel plot, Orwin fail-safe N and Duvall and Tweedie's Trim and Fill were used to test the publication bias. These three statistics are chosen since they are understandable and highly used in the literature (Üstün & Eryılmaz, 2014). Table 2 shows the publication bias test results of the studies included in the meta-analysis.

Table 2. Results of publication bias test

Number of Studies Included	Number of Study required for Orwin fail-safe N "Insignificant" SOF	Duvall and Tweedie's Trim and Fill Method	
		Number of Studies Added	Observed (Filled) for SOF
34	SOF 3057 for 0.01	4	0.94 (0.86)

Orwin fail-safe N is used to calculate how many more studies that can reduce the overall effect size calculated by considering the sample of the conducted study to trivial level might not be added into the meta-analysis. If this number is more than 5 to 10 times the number of studies included, this result is interpreted as there is no bias problem for meta-analysis (Borenstein et al., 2013). As a result of the analysis, Orwin fail-safe N was calculated as 3057. The number of studies required for the mean effect size of 0,94 found as a result of the meta-analysis to reach 0.01 level (trivial), that is almost zero effect size, is 3057. This obtained number is 90 times the number of studies included. However, 34 studies included are all the studies conducted for the question of this study in Turkey and meeting the study inclusion criteria. Besides, the fact that it is not possible to reach 3057 more studies is an indicator that there is no publication bias in this meta-analysis.

Another test used in the publication bias is Duvall and Tweedie's Trim and Fill. In this test, the points that cause distortion of the symmetry in the funnel plot are determined and these points are filled in the second step and the overall effect size is recalculated. The increase in the difference between the two overall effect sizes is interpreted that there might be a publication bias (Card, 2012). According to Table 2, there was an insignificant difference like 0.12 between the effect size value observed and the virtual effect size created to correct the effect caused by the publication bias.

On the other hand, Figure 2 shows the funnel plot results evaluated as a visual summary of the meta-analysis data set (Cooper et al., 2009) and showing the probability of publication bias.

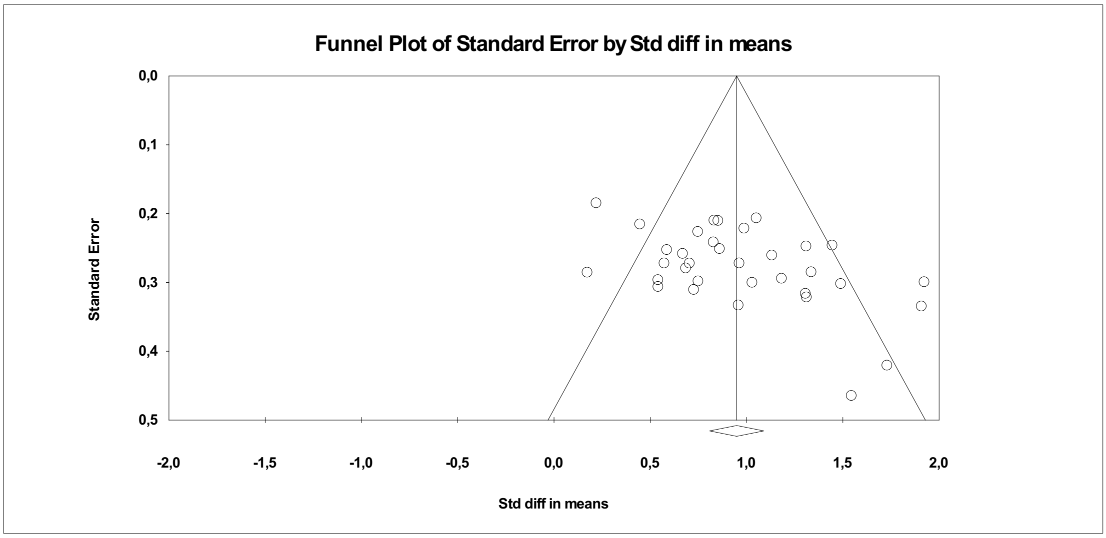

Figure 2. Funnel plot of the effect sizes

In the funnel plot, studies with small standard error values are gathered towards the top of the funnel shape and near to the mean effect size. Studies with high standard error values shifts towards the lower part of the figure because there are more sample variances in the estimation of the effect size in the studies with small number of sample (Borenstein et al., 2013). The fact that 34 studies were distributed in a symmetrical manner indicated that there was no publication bias.

Figure 3 shows the normal distribution graph of the effect sizes of the studies included in the study.

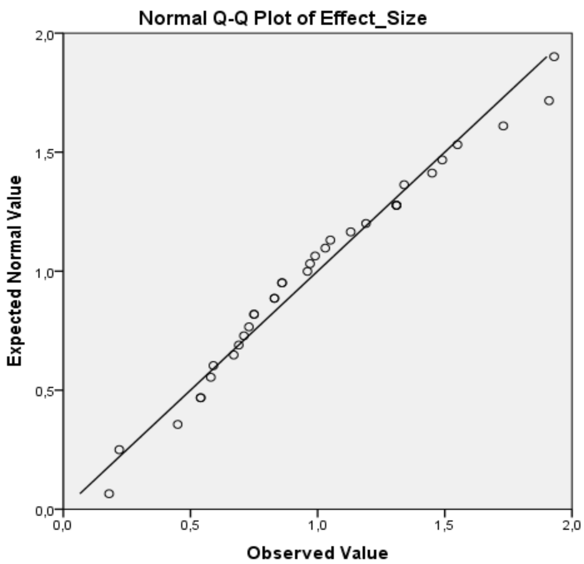

Figure 3. Normal distribution plot for effect sizes

The fact that the general distribution of the effect sizes of the studies was around the x=y line and there are no direct deviations showed that the effect sizes were suitable for normal distribution. The fact that the skewness (0.41) and kurtosis (-0.24) values for the effect sizes were in the range of -1.5 and +1.5 indicated that the data showed normal distribution (Tabachnick & Fidell, 2013). The result of Kolmogorov-Smirnov test (p>.05) also indicated that the effect sizes were suitable for normal distribution. All these results suggested that it was appropriate to combine 34 studies for meta-analysis (Rosenberg, Adams & Grevitch, 2000).

Results About the Overall Effect Size

Table 3 shows the results of the meta-analysis, which includes a comparison on the effect of student-centered teaching methods and traditional teaching methods in science laboratories on academic achievements of the students.

Table 3. Results about the homogeneity test of the studies according to the fixed effects model

Homogeneity Value (Q)	df	Chi-Square Table Value (χ^2)	p	I^2 Value (I-square)
79.41	33	43.77	0.00	58.44

In this table, since Q statistical value (79.41) is bigger than chi-square (χ^2) value (43.77) with 33 degrees of freedom at significance level of 95% when the homogeneity value of the studies is calculated according to the fixed effects model, it can be asserted that the distribution of the effect sizes had a heterogeneous characteristic. In addition, I^2 value which is a complement of Q statistics was found to be moderately heterogeneous with 58.44%.

Table 4. Results of the effect size according to the random effects model

Mean Effect Size (ES)	k	Standard error	95% Confidence Interval Lower limit	Upper Limit	Z	p
0.94	34	0.07	0.80	1.09	13.19	0.00

k: number of studies

Table 4 shows that the mean effect size value was calculated as 0.94 with 1.09 upper limit and 0.80 lower limit at 95% confidence interval and 0.07 standard error according to the random effects model of the studies (z=13.19; p=0,00). The mean effect size value of +0.94 showed that the laboratory-based science teaching applications had a positive effect on the academic achievements of the students in favor of the experimental group according to the classification by Cohen et al. (2011). Figure 4 shows the forest plot of the effect sizes of the studies according to the random effects model.

Study Name	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
	Statistics for each study						
Acar Şeşen and Mutlu, 2016	1,493	0,303	0,092	0,899	2,086	4,930	0,000
Açışlı, 2014	1,339	0,286	0,082	0,779	1,899	4,688	0,000
Aksakal et al., 2015	1,315	0,322	0,104	0,683	1,946	4,080	0,000
Alkan and Koçak, 2015	1,733	0,421	0,178	0,907	2,559	4,112	0,000
Alkan, 2016	0,961	0,334	0,112	0,306	1,615	2,876	0,004
Arslan, 2016	1,912	0,335	0,113	1,254	2,569	5,699	0,000
Ayvacı et al., 2015	0,835	0,211	0,044	0,422	1,248	3,962	0,000
Ayvacı and Yıldız,2013	0,855	0,211	0,045	0,441	1,269	4,051	0,000
Balaban, 2014	1,926	0,300	0,090	1,338	2,514	6,417	0,000
Bıyıklı, 2014	0,671	0,259	0,067	0,164	1,179	2,592	0,010
Çinici et al., 2013	0,688	0,280	0,078	0,139	1,237	2,455	0,014
Güler, 2016	1,054	0,207	0,043	0,648	1,461	5,085	0,000
Kara, 2018	0,176	0,286	0,082	-0,385	0,737	0,614	0,539
Karaçöp, 2017	0,752	0,299	0,089	0,166	1,338	2,515	0,012
Köklü, 2015	0,223	0,185	0,034	-0,141	0,586	1,200	0,230
Köklükaya et al., 2016	1,186	0,295	0,087	0,607	1,764	4,018	0,000
Oymak, 2018	1,448	0,247	0,061	0,964	1,932	5,864	0,000
Şekerci, 2013	0,991	0,222	0,049	0,555	1,426	4,458	0,000
Şimşir et al., 2018	0,863	0,252	0,063	0,369	1,357	3,426	0,001
Tatlı and Ayas, 2013	0,965	0,273	0,074	0,430	1,500	3,538	0,000
Toprak and Çelikler, 2017	1,310	0,317	0,100	0,688	1,931	4,131	0,000
Turan, 2018	0,544	0,297	0,088	-0,039	1,126	1,829	0,067
Ulu and Bayram, 2015	0,589	0,253	0,064	0,093	1,086	2,325	0,020
Ural, 2016	0,831	0,242	0,059	0,356	1,306	3,429	0,001
Ünal, 2018	0,576	0,273	0,074	0,041	1,110	2,109	0,035
Yıldırım and Altun, 2015	0,750	0,227	0,052	0,305	1,196	3,304	0,001
Yilmaz and Karaçöp, 2018	1,032	0,301	0,091	0,442	1,622	3,429	0,001
Demircioğlu and Uçar, 2015	1,313	0,248	0,062	0,826	1,799	5,289	0,000
Ürey and Aydın, 2014	0,544	0,307	0,094	-0,058	1,146	1,771	0,077
Yavuz and Kıyıcı, 2014	0,449	0,216	0,047	0,025	0,873	2,076	0,038
Durmuş, 2014	0,729	0,311	0,097	0,119	1,339	2,342	0,019
Kılınç Alpat et al., 2018	1,548	0,465	0,217	0,636	2,460	3,326	0,001
Tiftikçi et al., 2017	0,707	0,273	0,075	0,172	1,242	2,589	0,010
Kırıktaş, 2014	1,135	0,261	0,068	0,622	1,647	4,340	0,000

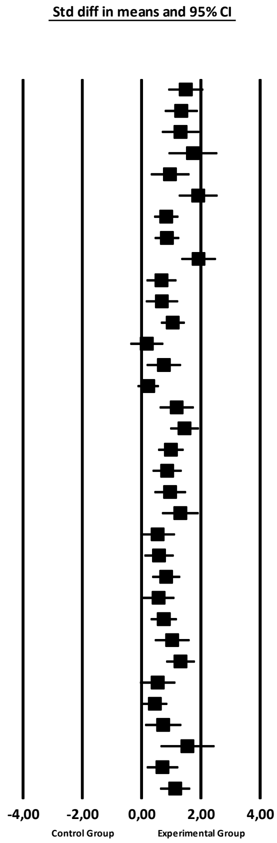

Figure 4. The forest plot showing the distribution of the effect size values of the studies

While the black squares seen in Figure 4 showed the determined effect size of that study, the horizontal lines on both sides of each square showed the top and lower limits of the effect size of that study at confidence interval of 95%. The length of the horizontal lines here indicated the width of the confidence interval. The rhombus at the bottom of all squares shows the overall effect size of all studies (Borenstein et al., 2013). When the overall statistical results of the effect sizes were examined, it was understood that all of a total of 34 studies had a positive effect. When the graph was examined, it was seen that 14 studies had a strong effect size, 18 studies had a moderate effect size, the studies had a small effect size, and 1 studies had a weak effect size. It was determined that while the study having the lowest effect size was the study by Kara (2018) with value of 0.18; the study by Balaban (2014) had the highest effect size of 1.93.

The Results Concerning Characteristics-Related Problem of the Studies

Table 5 shows the results concerning whether or not the effect sizes varied according to the variables of educational level, teaching methods, publication types, science areas, and application regions in terms of the academic achievement in laboratory courses.

Table 5. Effect size comparisons according to the study characteristics

Study Characteristics	Intergroup Homogeneity (QB)	p	k	Effect Size	Confidence Interval of 95%		Standard Error
					Lower Limit	Upper Limit	
Educational Level	**4.30**	**0.11**					
Undergraduate			28	0.96	0.80	1.12	0.08
High School			2	1.22	0.74	1.69	0.24
Secondary School			4	0.70	0.42	0.97	0.14
Publication Types	**0.21**	**0.64**					
Articles			23	0.91	0.77	1.06	0.07
Theses			11	1.00	0.68	1.33	0.16
Science Areas	**1.17**	**0.76**					
Biology Laboratory			5	1.01	0.42	1.61	0.30
Science Laboratory			11	0.88	0.65	1.11	0.11
Physics Laboratory			9	0.88	0.61	1.16	0.14
Chemistry Laboratory			9	1.23	0.83	1.23	0.10
Teaching Methods	**5.74**	**0.57**					
Open-Ended Laboratory			3	0.78	0.46	1.11	0.16
Argumentation			4	0.99	0.72	1.26	0.13
Collaborative			4	1.06	0.54	1.59	0.26
Model Using			2	1.24	0.81	1.67	0.21
Learning Cycle			5	1.21	0.82	1.59	0.19
Questioning-Based			3	0.85	0.54	1.15	0.15
Technology-Aided			7	0.78	0.36	1.21	0.21
EOE			3	0.97	0.46	1.47	0.25
Application Regions	**3.84**	**0.69**					
Mediterranean			3	1.06	0.80	1.32	0.13
Eastern Anatolia			3	1.19	0.57	1.80	0.31
Aegean			2	1.23	0.78	1.68	0.22
Southeastern Anatolia			2	0.84	0.44	1.25	0.20
Central Anatolia			4	1.07	0.69	1.46	0.19
Black Sea			13	0.85	0.62	1.09	0.12
Marmara			4	0.92	0.41	1.43	0.25

Mean effect size values of the groups which were formed according to educational levels were calculated as 0.96 for undergraduate education (at confidence interval of 95%; lower limit 0.80, upper limit 1.12), 1.22 for high school (at confidence interval of 95%; lower limit 0.74, upper limit 1.69), and 0.70 for secondary school (at confidence interval of 95%; lower limit 0.42, upper limit 0.97). According to Cohen et al. (2011), the effect sizes were moderate in secondary school and undergraduate levels; and high in high education. Additionally, effect sizes did not show a significant difference (p=0.11) between the groups.

Mean effect size values of the groups which were formed according to publication types were calculated as 1.00 for theses (at confidence interval of 95%; lower limit 0.68, upper limit 1.33) and 0.91 for articles (at confidence interval of 95%; lower limit 0.77, upper limit 1.06). According to Cohen et al. (2011), the effect sizes were moderate in both theses and articles. However, these effect sizes did not show a significant difference (p=0.64) between the groups.

Mean effect size values of the groups which were formed according to science areas were calculated as 1.01 for biology laboratory (at confidence interval of 95%; lower limit 0.42, upper limit 1.61), 0.88 for science laboratory (at confidence interval of 95%; lower limit 0.65, upper limit 1.11), 0.88 for physics laboratory (at confidence interval of 95%; lower limit 0.61, upper limit 1.16), and 1.23 for chemistry laboratory (at confidence interval of 95%; lower limit 0.83, upper limit 1.23). According to Cohen et al. (2011), the effect sizes were moderate in science and physics laboratories and high in biology and chemistry laboratories. However, these effect sizes did not show a significant difference (p=0.76) between the groups.

Mean effect size values of the groups which were formed according to teaching methods were calculated as 0.78 for open-ended laboratory method (at confidence interval of 95%; lower limit 0.46, upper limit 1.11), 0.99 for argumentation (at confidence interval of 95%; lower limit 0.72, upper limit 1.26), 1.06 for collaborative (at confidence interval of 95%; lower limit 0.54, upper limit 1.59), 1.24 for model using (at confidence interval of 95%; lower limit 0.81, upper limit 1.67), 1.21 for learning cycle (at confidence interval of 95%; lower limit 0.82, upper limit 1.59), 0.85 for questioning-based (at confidence interval of 95%; lower limit 0.54, upper limit 1.15), 0.78 for technology-aided (at confidence interval of 95%; lower limit 0.36, upper limit 1.21) and 0.97 for EOE (at confidence interval of 95%; lower limit 0.46, upper limit 1.47). The table showed that collaborative, model using and learning cycle methods affected academic achievement strongly; whereas, other methods had a moderate effect. However, the effect sizes did not show a significant difference (p>.05) between the groups.

Mean effect size values of the groups which were formed according to application regions were calculated as 1.06 for the Mediterranean region (at confidence interval of 95%; lower limit 0.80, upper limit 1.32), 1.19 for the Eastern Anatolia region (at confidence interval of 95%; lower limit 0.57, upper limit 1.80), 1.23 for the Aegean region (at confidence interval of 95%; lower limit 0.78, upper limit 1.68), 0.84 for the Southeastern Anatolia region (at confidence interval of 95%; lower limit 0.44, upper limit 1.25), 1.07 for the Central Anatolia region (at confidence interval of 95%; lower limit 0.69, upper limit 1.46), 0.85 for the Black Sea region (at confidence interval of 95%; lower limit 0.62, upper limit 1.09) and 0.92 for the Marmara region (at confidence interval of 95%; lower limit 0.41, upper limit 1.43). According to Cohen et al. (2011), the effect sizes were strong with 1.23 in the Aegean region having the highest value and moderate with 0.84 in the Southeastern Anatolia region having the highest value, in terms of application regions. However, the effect sizes did not show a significant difference (p=0.69) between the groups according to application regions.

Results Concerning the Meta-Regression Between Application Duration and Effect Size

Figure 5 and Table 6 show the results of the meta-regression analysis concerning the effect of student-centered teaching methods in science laboratories on academic achievements of the students, in terms of application durations and effect sizes.

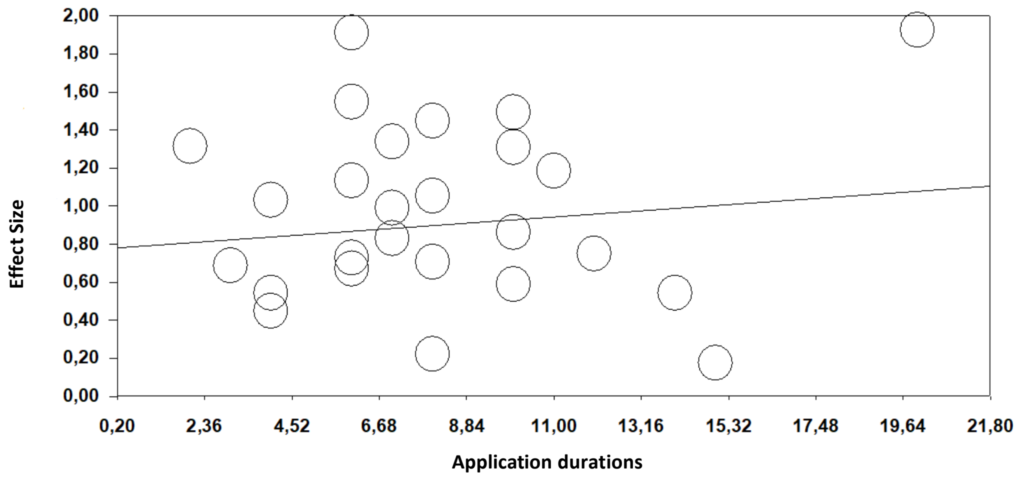

Figure 5. Meta-regression analysis concerning application durations and effect sizes

As is seen in the Figure, application durations varied between 0.20 and 21.80 and the effect sizes varied between 0.00 and 2.00.

When examining Table 6; as a result of the meta-regression analysis which was performed to determine the effect of student-centered teaching methods in science laboratories on academic achievements of the students according to application durations, it was observed that there was no significant effect (z=1.04468, p>.05). This condition showed that student-centered teaching methods used in science laboratories had a positive effect on academic achievements of the students independent from application durations.

Table 6. The results concerning the meta-regression between application durations and effect sizes

	Regression Coefficient	Standard Error	Lower Limit	Upper Limit	Z	p
Application Duration	0.01504	0.01440	-0.01318	0.04327	1.04468	0.29617
Intercept	0.77760	0.12808	0.52657	1.02864	6.07127	0.00000

*26 studies were included in the meta-regression analysis.

Results Concerning the Meta-Regression between Sample Size and Effect Size

Figure 6 and Table 7 show the results of the meta-regression analysis concerning the effect of student-centered teaching methods in science laboratories on academic achievements of the students, in terms of sample size and effect size.

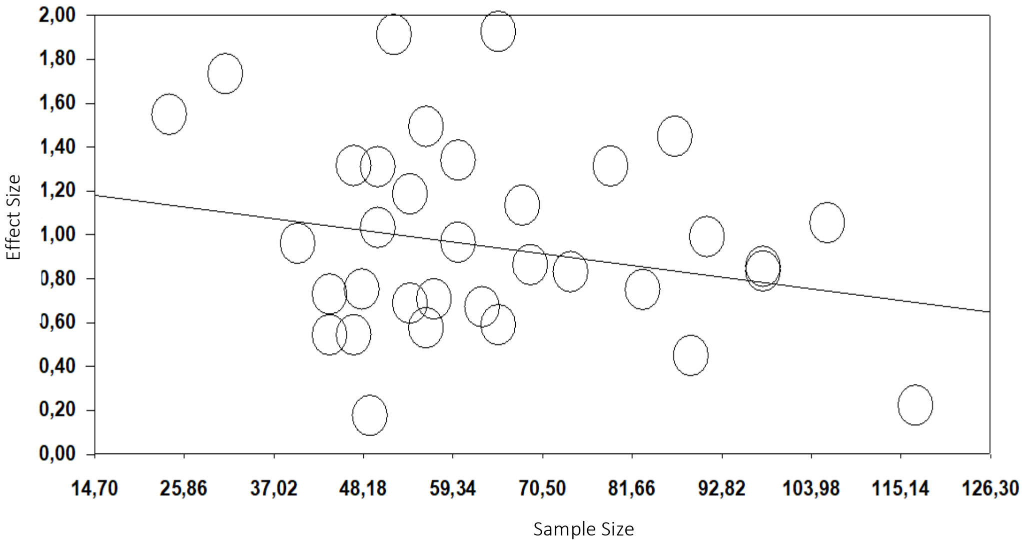

Figure 6. Meta-Regression analysis between sample size and effect size

As is seen in the Figure 6, while sample size varied between 14.70 and 126.30, the effect sizes varied between 0.00 and 2.00. When examining Table 7; as a result of the meta-regression analysis which was performed to determine the effect of student-centered teaching methods in science laboratories on academic achievements of the students according to sample size, it was observed that there was a negative significant effect (z= -2.36450, p<.05). According to the point estimate value calculated (-0.00981), a unit of increase in the sample size caused a decrease of 0.00477 in the effect of student-centered teaching methods in science laboratories on academic achievements of the students. This condition shows that as the sample size decreased, the effect of student- centered teaching methods in science laboratories on academic achievements of the students increased.

Table 7. Results Concerning the Meta-Regression Analysis between Sample Size and Effect Size

	Regression Coefficient	Standard Error	Lower Limit	Upper Limit	Z	p
Sample Size	-0.00477	0.00202	-0.00873	-0.00082	-2.36450	0.01805*
Intercept	1.25064	0.15157	0.95357	1.54771	8.25128	0.00000

p< .05

DISCUSSION

The first question of the study is, “How do student-centered teaching methods in science laboratories affect academic achievements of the students, compared to traditional laboratory method?”. For that purpose, the overall effect size value of the studies was determined as 0.94 by using random effects model in the present study. According to the effect size classification by Cohen et al. (2011), this value was positive and moderate. This result shows a parallelism with many national and international studies suggesting that student-centered laboratory applications have a significant effect on achievements of the students who receive education in various stages from primary education to university (Akkağıt & Tekin, 2012; Arslan, 2016; Ayvacı & Yıldız, 2013; Bozkurt & Sarıkoç, 2008; Demircioğlu & Uçar, 2015; Karalar & Sarı, 2007; Karamustafaoğlu, Aydın & Özmen, 2005; Nirmalakhandan et al., 2007; Ong & Manan, 2004; Oymak, 2018; Özdener, 2005; Pektaş, Çelik, Katrancı & Köse, 2009; Salgut 2007; Ulu & Bayram, 2015). In the study by Demirtaş (2014), he combined 1 doctoral dissertation, 17 master’s theses, 10 articles and 2 papers conducted in Turkey between 2000-2012 to investigate the effect of the laboratory-based teaching method on the student’s achievement in science education via meta-analysis method that laboratory-based teaching affected the academic achievement in huge level according to the classification made by Thalheimer & Cook (2002). On the other hand, a literature review was conducted in order to compare the effect of laboratory-based science education on the academic achievement of the students in Turkey with the other countries in the present study, but no meta-analysis study conducted abroad about this issue was found. However, in the meta-analysis studies determined in the literature, it has been determined that the student-centered methods such as brain-based learning (Gözüyeşil & Dikici, 2014), project-based learning (Ayaz & Söylemez, 2015), cooperation-based learning (Capar & Tarım, 2015; Gözübatık Tarım, 2003; Kaldırım & Tavşanlı, 2018), and problem-based learning (Dağyar & Demirel, 2015) are effective on the academic achievements of the secondary and higher education students.

The second question of the study is, “Does the effect of student- centered teaching methods in science laboratories on academic achievements of the students vary according to study characteristics?”. In the study, 4 secondary education level studies, 2 high school level studies and 28 undergraduate education level studies were included in the meta-analysis according to educational levels. Mean effect size values of the groups which were formed according to educational levels were calculated as 0.96 for undergraduate education, 1.22 for high school, and 0.70 for secondary school. According to Cohen et al. (2011), the effect sizes were moderate in secondary and undergraduate education levels and strong in high school level. However, the effect sizes do not show a significant difference (p=0.11) between the groups.

In the study, 5 doctoral theses, 6 postgraduate theses and 23 articles were included in the meta-analysis. Mean effect size values of the groups which were formed according to publication types were calculated as 1.00 for theses and 0.91 for articles. According to Cohen et al. (2011), the effect sizes were moderate. On the other hand, when examining the frequency and percentage values of the studies that were gathered up for the meta-analysis according to publication types, it was observed that only 5 out of 34 studies, in other words 15% of them consisted of doctoral theses, whereas 6 (18%) consisted of postgraduate theses. Limited number of especially doctoral and postgraduate theses examining the effect of laboratory-based teaching methods in science education on academic achievement reveals the necessity of increasing the number of such studies. It is thought that increasing the number of doctoral and postgraduate theses will affect the effect size value obtained from the meta-analysis studies conducted.

There were 11 studies in the science laboratory area, 5 studies in the biology laboratory area, 9 studies in the physics laboratory area and 9 studies in the chemistry laboratory area. Mean effect size values of the groups which were formed according to science areas were calculated as 1.01 for biology laboratory, 0.88 for science laboratory, 0.88 for physics laboratory, and 1.23 for chemistry laboratory. According to Cohen et al. (2011), the effect sizes were moderate in science and physics laboratories and strong in biology and chemistry laboratories. However, the effect sizes do not show a significant difference (p=0.76) between the groups. The fact that effect sizes were higher in biology and chemistry laboratories could be associated with the students' ability to transfer daily life examples to the laboratory environment more easily. According to this result; there were 3 studies in open-ended laboratory method, 1 study in argumentation, 4 studies in collaborative, 2 studies in model using, 5 studies in learning cycle, 4 studies in questioning-based, 7 studies in technology-aided and 3 studies in EOE method used in increasing academic achievement via laboratory-based approaches, which are used in teaching different lessons. Mean effect size values of the groups which were formed according to teaching methods were calculated as 0.78 for open-ended laboratory, 0.99 for argumentation, 1.06 for collaborative, 1.24 for model using, 1.21 for learning cycle, 0.85 for questioning-based, 0.78 for technology-aided, and 0.97 for EOE. According to Cohen et al. (2011), the effect sizes were higher in collaborative, model using and learning cycle methods and moderate in other methods. However, effect sizes did not show a significant difference (p=0.57) between the groups. This result showed that collaborative, model using and learning cycle methods in science laboratories were more effective on increasing academic achievement of the students.

According to application regions in the study, there were 3 studies in the Mediterranean region, 3 studies in the Eastern Anatolia region, 2 studies in the Aegean region, 2 studies in the Southeastern Anatolia region, 4 studies in the Central Anatolia region, 13 studies in the Black Sea region and 4 studies in the Marmara region. Mean effect size values of the groups which were formed according to application regions were calculated as 1.06 for the Mediterranean region, 1.19 for the Eastern Anatolia region, 1.23 for the Aegean region, 0.84 for the Southeastern Anatolia region, 1.07 for the Central Anatolia region, 0.85 for the Black Sea region, and 0.92 for the Marmara region. According to Cohen et al. (2011), the effect sizes were strong with 1.19 in the Aegean region having the highest value and moderate with 0.84 in the Southeastern Anatolia region having the lowest value, in terms of application regions. However, the effect sizes did not show a significant difference (p=0.69) between the groups according to application regions. In other words, it is possible to state that effect sizes were similar on laboratory-based academic achievements of the students from different geographical regions.

The third question of the study is, "Is there a significant correlation between the effect of student- centered teaching methods in science laboratories on academic achievements of the students and application durations?". As a result of the meta-regression analysis, it was determined that there was no significant correlation between effect sizes and application durations (z=1.04468, p>.05). This condition showed that student-centered teaching methods used in science laboratories had a positive effect on academic achievements of the students independent from application durations.

The fourth question of the study is, "Is there a significant correlation between the effect of student- centered teaching methods in science laboratories on academic achievements of the students and sample size?". As a result of the meta-regression analysis, it was determined that there was a significant correlation between effect size and sample size (z=-2.36450, p<.05). This shows that laboratory applications performed on smaller sample groups have a higher effect on academic achievements of the students.

CONCLUSION AND RECOMMENDATIONS

This meta-analysis study included 34 studies conducted in Turkey between 2013-2018 and having a total sample size of 210. The overall effect size value of the studies was determined as 0.94 by using random effects model in the present study. According to the effect size classification by Cohen et al. (2011), this value was positive and moderate. Funnel plot, Orwin fail-safe N and Duvall and Tweedie's Trim and Fill results formed to determine if there is a publication bias in terms of the studies included in the study showed that there was no publication bias. In order to reduce the effect size of 34 studies combined with meta-analysis method to the effect size value of 0.01, at least 3057 studies with zero effect size are needed. Considering the high number of studies, it can be asserted that the obtained analysis results are reliable.

As a result of the moderator analyses, it was concluded that effect sizes did not vary according to the variables of educational level, teaching methods, publication types, science areas and application regions. As a result of the meta-regression analyses, it was determined that there was no significant correlation between effect size and application durations; whereas, there was a negative significant correlation between effect size and sample size.

Based on the results of the study, the following recommendations were developed:

1)This meta-analysis study showed that laboratory-based science teaching had a moderate and positive effect on the academic achievements of the students compared to the traditional teaching methods. For this reason, the laboratory applications should take place on the top of the methods preferred for an effective learning by the science field teachers.

2) When the frequency and percentage values of the studies combined together for the meta-analysis study in terms of the publication type were examined, it was observed that only 5 (15%) of 34 studies were doctoral dissertation and 6 of them (18%) were master's theses. The low number of master's and doctoral theses on the effect of the laboratory-based teaching methods on the academic achievement of the students revealed the necessity to increase the number of such studies.

3) In the study, examining the effect sizes of the laboratory application approach on academic achievements according to "educational levels", it was determined that the highest effect size was observed in high school level. According to this result, it can be suggested to use student-centered teaching methods especially in high school level in order to increase academic achievements of the students in science lessons.

4) In this meta-analysis, it was determined that there was a negative significant correlation between "sample size" and "effect sizes". Accordingly, it can be suggested to study with smaller samples in order to increase academic achievements.

5) It is recommended in the future studies to conduct studies at international level by expanding this framework and to conduct comparative meta-analysis studies on the country basis about the subject.

6) In this meta-analysis study, the effect of the laboratory-based science education applications on the academic achievements of the students was examined and its other effects were excluded from the study. It can be recommended for the researchers to conduct studies investigating the effect of laboratory-based science teaching on not only the academic achievement but also different affective characteristics such as persistence, motivation, self-efficacy, and scientific process skills.

7) In the study, examining "educational levels"; it was determined that the studies included in the meta-analysis were conducted mostly in undergraduate educational level. On the other hand, it was found that there was a limited number of studies in high and secondary school levels. Thus, it can be suggested to increase the number of studies to be conducted with the students in high and secondary school levels.

8) It is thought that this study as a meta-analysis work conducted on the effectiveness of the laboratory-based teaching will provide contribution to the literature and it will be helpful for future studies.

Declaration of Conflicting Interests

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Statements of publication ethics

We hereby declare that the study has not unethical issues and that research and publication ethics have been observed carefully.

Researchers' contribution rate

The study was conducted and reported with equal collaboration of the researchers.

Ethics Committee Approval Information

Ethics committee report is not required since the data of the our study is before 2020

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Appendix 1. Studies Included in the Meta-Analysis

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