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A Meta-Analysis of the Effects of Laboratory Based Teaching on Students' Learning

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Abstract: The purpose of this study was to examine the relationship between laboratory-based teaching methods on science education and student success, by using meta-analysis. The research results were reported from 2000 to 2012 years in Turkey which analyzed the effects of laboratory-based teaching methods on student successes. The meta-analysis methods were from, one PhD dissertation, 17 Master's thesis and 12 published articles which were the main sources used to demonstrate the influence of laboratory based teachings on science education. Thalheimer also showed that laboratory based teaching in a significant degree affects academic success. The results demonstrate that laboratory-based teaching methods significantly influence academic success +2,8729 size.

Keywords: Laboratory Based Teaching, Science Learning, Meta-Analysis

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1. Introduction

To advance society a better learning situation can be achieved by the education of individuals in rapidly developed science and technology (Soslu, Dilber and Duzgun, 2011). Education is the process of making changes in individual's behaviors. Education activities need to be planned to make students to gain behavior changes (Kaya and Kavcar, 2002). In order to better educate students, laboratory activities should be used by students. Students' educational development was realized by experiments with laboratory based science education (Selek, Turkmen and Yalcin, 2003).

A good science education can be efficiently performed if laboratories and experiments based lessons are taught (Karaca, Ulucinar and Cansaran, 2006). Laboratories provides to relate the connections among different subjects and explain the specific characteristics of a particular subject (Tezcan and Aslan, 2007). The access to students' necessary information in a very short time as well as their use of experimental approaches can be realized by laboratory based science education (Erokten, 2010).

The purpose of gathering thirty different studies in one group is to demonstrate the effect of a laboratory based teaching method on student achievements. In this study, a literature review about how laboratory based teaching method affects student success has been made. These thirty studies were gather data in one group, using meta-analysis methods. This paper attempts to analyze the effect of laboratory based teaching on the changes of students' general achievements.

1.1. Study Problem

Many studies which are about similar problems can be found when searching about studies on laboratory-based teaching. However, there is not any study concern the effect size of the laboratory-based teaching method. The revealing the effect size is needed to make a meta-analytic effect analysis. The question of laboratory based education in Turkey in level effects on student success is the main problem of this study.

It is known that the importance of science experiments which can make individuals engage with scientific research processes which developed their communication skills (Yildiz et al, 2007). The main purpose of this study is to reveal the effect size of laboratory based teaching on student success. In Turkey, laboratory-based teaching studies were gathered together and a meta-analytic effect size was tried to find. Thirty different studies were used together to reach the common effect size of laboratory-based teaching on students' academic success.

2. Methodology

Today, the number of scientific studies is rapidly increasing in education as in all fields. One needs to spend days or even months to examine all the great number of increasing sources, and findings to review, to account for the results and recommendations. This document multiplicity makes it difficult to reach the huge amount of sources. The need to arrange these sources under one roof, and again be passed through a process of analysis, new comment review and new insights (Saglam and Yuksel, 2007).

Quantitative methods to combine the results of studies are defined in early 1930s for the first time. In the 1970s interest grew, and the first applications in the health field in particular were observed. In 1976, these kinds of researches were called "Meta-analysis". In 1987, statistical methods for meta-analysis of non-experimental studies and in 1994 statistical methods of meta-analysis are in detail defined (Akgoz et al, 2004; Rosenberg et al, 2000).

Meta-analysis purposes that combined results of multiple studies were made in a specific case and independent from each other and doing the statistical analysis findings. This method, summarizes the results of various studies in the fields of science and provides common judgment with the conclusions (Saglam and Yuksel, 2007; Karasoy and Ata, 2008; Acar, 2011; Kaya, 2013).

In a Meta-analysis study, statistical results are combined after specifying studies are included and doing qualitative analysis. The statistical model should be specific by research results since it is used for combining them. In meta-analysis, there can be used two statistical method named Fixed Effect Model and Random Effect Model (Topcu, 2009; Yesilyurt, 2010; Yesilyurt, 2011; Acar, 2011).

A fixed effect model is hypothetical of all studies forecast completely the same effect. Besides, getting results in this model completely depends on working conditions.

This model's basic features are:

1. Narrower confidence intervals can be achieved.

2. Since variance component between studies is not considered, clear information about homogeneity of studies cannot be reached.

3. Small studies may not be as sensitive as the large studies.

Fixed effect model assumes that variance between the results of study originate related data. When fixed effect model assumptions is not recovered, random effect model which has both inter studies variance and in study variance, should be preferred.

When the studies are not homogenous or fixed effect model is not appropriate to use, random effect model is the right choice. In this model, a larger confidence interval is generated by component of variance between studies. The random effect model is more preferred than the fixed effect model. Because, in meta-analyses which were made with this model both all alterations between studies and alterations per study, are included.

Effect size is the base of meta-analysis which was presented by Cohen in (1988). "Effect size" was explained as frequency of a phenomenon in public. Effect size can be assumed as variation index between a control group and an experimental group. If effect size is numerical, it is based upon averages; if the result is nominal, it is based upon rates; if the result indicates a relation, it is based upon correlation. Effect size classification for the sizes based upon averages follow:

- If effect size value is 0.20 small level affects,
- If effect size value is 0.50 medium level affects,
- If effect size value is 0.80 large level affects (Ozdemirli, 2011).

More detailed classification was made by (Thalheimer and Cook, 2002) as below;

- -0,15<Effect size value < 0,15 negligible,
- 0,15< Effect size value < 0,40 small,
- 0,40< Effect size value < 0,75 medium,
- 0,75< Effect size value < 1,10 large,
- 1,10< Effect size value < 1,45 very large,
- 1,45< Effect size value huge, level affects.

In this research, studies which search for the effect of laboratory-based teaching method on student success were analyzed. To make a common decision upon these studies, a meta-analysis method has been used. Besides, fixed effect model is used in this study. While performing the sample of study, experimental researches were preferred. As a result, 30 studies and 37 statistical data from these studies were combined.

Inclusion criteria to the study for data are listed below:

- Studies should be made from 2000 to 2012 years.
- It should be published in online academic journals or periodical academic publications,
- Studies should be academic studies composed by postgraduate theses.
- Experimental and Control Groups should be included in studies.
- Experimental group should represent to groups that use laboratory based teaching.
- Students do science laboratory experiments themselves under the guidance of teachers.
- Control group should represent the groups' use traditional teaching.
- The average value (M) and standard deviation (SD) should exist for the groups.

Coding scheme for this study was composed of two sections. In the first section, study number, writer names, place and year were written to identify the study. In second section, number of subject per group (N), average values (M) and standard deviations (SD) were recorded.

In this study, Study Effect Meta-Analysis method was used for analyzing data. Main purpose of this method is to calculate differences between averages which is formulized as d= (Xe-Xc)/SD, of control and experimental groups (Sahin, 2005; Kinay. 2012). Excel 2010 and Metamix 2.0 have been used for calculations and drawing graphs.

3. Findings

This study researches the effect of laboratory-based study on academic success in science education. A meta-analysis has been made by using thirty studies' sample numbers, standard deviations and averages. Studies which were published from 2000 to 2012 were included. Students science laboratory experiments themselves under the guidance of teachers. It is seen that this study comprehends thirty-seven data and 2363 sample numbers. Twelve of the picking studies are physics, seven from chemistry and eleven from biology. The studies which are included the meta-analysis was chosen the fifteen different cities of Turkey.

Table 1. *Studies' Effect Size Direction's Frequency and Percentages*

Effect Size Direction	Frequency	Percentage
0 (Zero)	3	10%
+ (Positive)	24	80%
- (Negative)	3	10%

It is observed that negative effect size (10%) at three studies and positive effect size (80%) at twenty-four studies when looking in the direction of the effect size of studies. It is zero the effect size (neutral) (10%) of the three studies. The studies whose results are negative and neutral effect sizes used different methods which are constructivist, computer assisted instruction. These studies used the abovementioned methods in their experimental groups and laboratory based teaching in their control groups. Because this paper studies laboratory based teaching, the results of control groups and experimental groups are inversed in this study. In other words, this paper used the results of their experimental groups and the control groups. Nevertheless, the total effect size direction of studies is positive. This, laboratory-supported education shows that to be effective in science education. The effect size which formed by the difference between mean of experimental and control groups was calculated in the studies. Meta-analysis of Mean Difference Effects was used for calculate this effect size. The several studies of combined data, indicate with MD is converted the common effect size.

Table 2. *Effect Size Formulas and Transformation Table*

Statistics		Explanation
Means	**Effect size (MD) Transformation Formulas**	M_e=Experiment group's mean M_c= Control group's mean Ne=Experiment group's subject size
Variance	$MD = Me - Mc$	Nc= Experiment group's subject size S_e^2=Experiment group's variance S_c^2= Control group's variance

In Table 2 transformation formulas are given for effect size (MD). MIX-Version 1.7 (Meta-Analysis Made Easy) pack software was used in the meta analysis of related studies' data recorded.

Table 3. *Studies Experiment and Control Groups' Number, Average, Standard Deviation Values which are Unified with Meta Analysis Method*

Order	Writer	Date	N(e)	M(e)	Sd(e)	N(c)	M(c)	Sd(c)
Study 1	Cemil Aydogdu	2000	56	9	3,29	54	7,58	2,67
Study 2	Ilknur Guven, Ayla Gurdal	2000	16	7,3125	2,8218	16	5,0625	0,9979
Study 3	Ilknur Guven, Ayla Gurdal	2000	16	8,75	1,9833	16	6,3125	1,54
Study 4	Ramazan Cansoy	2001	19	9,5789	3,1148	22	7,5455	1,92
Study 5	Ramazan Cansoy	2001	19	7,9474	3,7635	22	5,6818	2,0092
Study 6	Ayhan Basak	2002	22	67,45	12,36	22	54,91	20,39
Study 7	Serap Kaya, Nevzat Kavcar	2002	29	73,45	9,01	32	65,43	7,62
Study 8	P. Yalcin, D. Yigit,, A. Sulun D. A.Bal, A. Bastug, M.Aktas	2002	31	69,35	1,94	28	58	3,16
Study 9	A. Telli, H.I. Yildirim, O.	2002	37	48,69	10,71	38	26,46	9,38

	Sensoy, N. Yalcin							
Study 10	Safiye Temel Aslan	2004	21	36,81	5,105	27	29,7	7,167
Study 11	Safiye Temel Aslan	2004	28	36,39	5,6	27	29,7	7,17
Study 12	Habibe Tezcan, Esra Bilgin	2004	22	10,55	2,3	20	8,7	2,18
Study 13	Ozlem Atici, Tahir Atici	2004	61	11,049	2,66	55	7,072	2,59
Study 14	Nevin Kozcu	2006	55	14,85	4,21	43	9,07	3,25
Study 15	Sevgi Eroglu	2006	24	19,67	0,96	28	17,18	0,612
Study 16	Semra Onel	2007	21	45,5	20,15	20	38,85	23,20
Study 17	Gulcan Uzun	2007	13	78,46	16,37	13	47,69	7,25
Study 18	B. Bayrak, U. Kanli, S. Kandil Ingec	2007	14	19,35	4,74	14	20,42	6,07
Study 19	Gulden Ozturk	2007	33	19,6061	3,9603	33	16,3939	4,51
Study 20	Kerim Onder	2007	14	17,21	4,96	14	15,5	5,03
Study 21	Erdal Basdas	2007	20	14,45	1,96	21	11,86	2,15
Study 22	Erdal Basdas	2007	20	14,45	1,96	22	12,32	2,36
Study 23	O. Ozyalcin Oskay, E. Erdem, A. Yilmaz	2008	52	66,31	12,01	47	61	20,71
Study 24	Tuna Maras	2008	53	17,17	4,15	61	12,9	4,44
Study 25	Aysegul Altun	2009	58	92,47	9,528	54	52,19	11,73
Study 26	Aysegul Altun	2009	58	59,21	10,059	54	52,19	11,73
Study 27	Payidar Baskurt	2009	20	19,05	2,86	20	11,8	3,41
Study 28	Y. Sulun, A. Evren, A. Sulun	2009	16	15,81	2,8	22	17,31	1,64
Study 29	Sibel Acisli, Umit Turgut	2009	41	18,07	2,98	41	23,83	1,84
Study 30	Ozay Soslu	2010	30	86,7	6,696	30	50,467	12,67
Study 31	Nazan Yildiz	2010	39	14,0256	4,9973	39	11,6667	4,56147
Study 32	Filiz Kara	2010	56	87,411	12,721	52	83,462	16,88
Study 33	Filiz Kara	2010	56	72,232	23,726	52	62,442	30,29
Study 34	Filiz Kara	2010	56	80,5	18,072	52	59,865	21,33
Study 35	Ali Azar, Ozlem Aydin Sengulec	2010	25	53,0	7,77	25	68	9,47
Study 36	Mursel Serdar Altinok	2011	17	70,5	18,16	18	45,06	16,81
Study 37	Mustafa Coramik	2012	20	78,7	9,251	21	69,143	14,01

In Table 3, sample numbers, average and standard deviation values of 30 units of independent studies the impact on student achievement of laboratory-supported education in science education from 2000 to 2012 are listed. Total 37 data are unified with meta-analysis package software and it is formed that sample of persons 2,363.

In order to determine whether Normal distribution of effect size is suitable for heterogeneity tests was conducted with MIX-Version 1.7 (Meta-Analysis MadeEasy) package software. Normal distribution graph is provided to effect size of studies in Diagram 1.

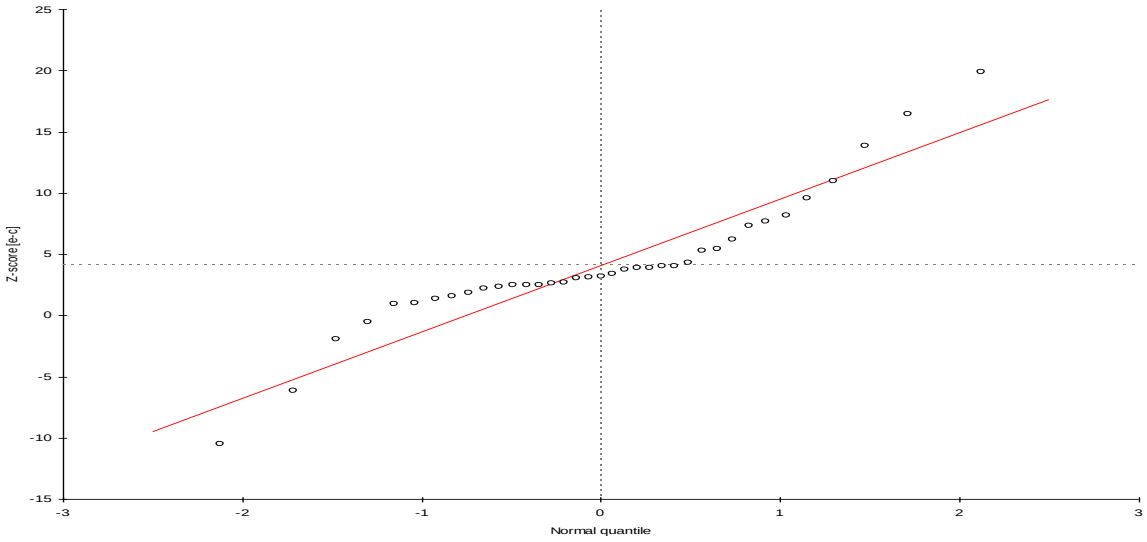

Diagram 1. *Effect size's Q-Q Graph of Normal Distribution*

The unified studies' effect size, general distribution's being among the trust space along X=Y line shows that it is close to the normal distribution.

As it is seen in Diagram 1, serious deviations are not observed in effect size. It is appropriate for normal distribution. This situation shows that unifying the studies used in meta-analysis study are statistically appropriate.

In order to evaluate statistical significance and homogeneity, calculations were conducted with MIX-Version 1.7 software and reached to z= 21,5471. According to this with p=0,000, this conclusion was reached that the analysis is statistically significant, the data are homogeneous. Because the data are homogeneous, constant effect data analysis method was preferred.

Table 4. *MIX Package Software Meta-Analysis Findings Calculated according to Constant Effect Model*

Number of Study	**37**	
Z Test Value	21,5471	
H Value	5,8113	
Number of Attended Subject	2363	Lower Limit-Top Limit
Constant Effect Meta Analysis Results	2,8729	2,6116-3,1343
Q Value	1215,7426	

Table 4 of the meta analysis was done in accordance with the constant effect model, p<0,0001 and 95 per cent confidence interval's lower limit 2,6116 and top limit 3,1343 average effect size ES=2,8729 was found and in sciences education, students do science laboratory experiments themselves under the guidance of teachers. Laboratory aided instruction method have a positive effect on students' academic success towards lessons conclusion has come out when compared to traditional teaching method.

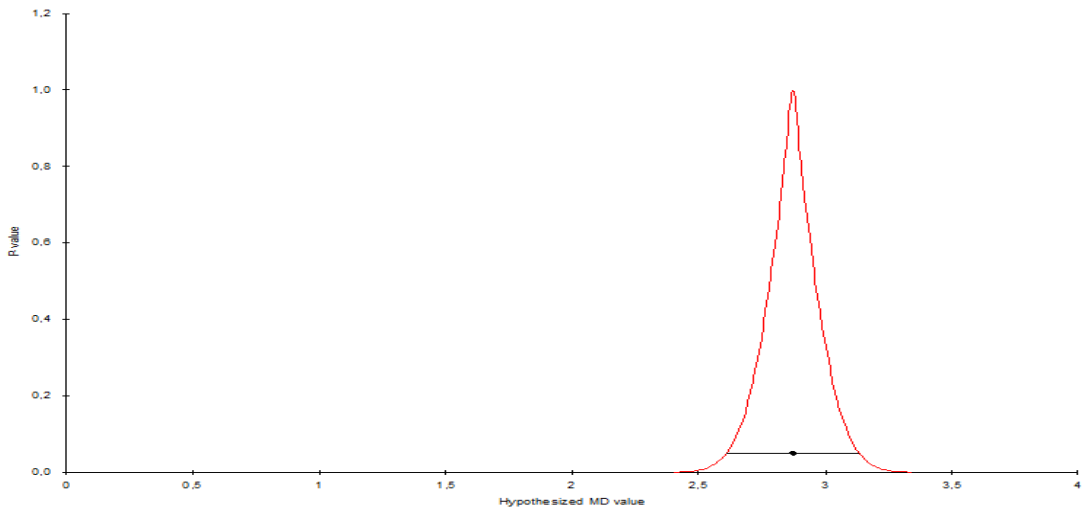

Diagram 2. *Standardized Effect Size Histogram*

In order to see effect size distribution, according to standardized histogram diagram in Diagram 2 which is formed in Metamix software, between 2,6 and 3,2 intervals, it is possible to say effect size regions are presented with high frequency. The graph of Effect Size (MD) and the Rejection Range is seen in Diagram 3. The related distribution doesn't show symptoms of heterogeneous like any fluctuations and deviation.

When a heterogeneity test result is p=0,0001 significance level, it should be cracked up as study findings are homogeneous. Thus, one single effect's existence on different study findings can be argued with fixed effect model. On this basis, students do science laboratory experiments themselves under the guidance of teachers, there is a common effect of laboratory-based teaching on academic success in science education can be told.

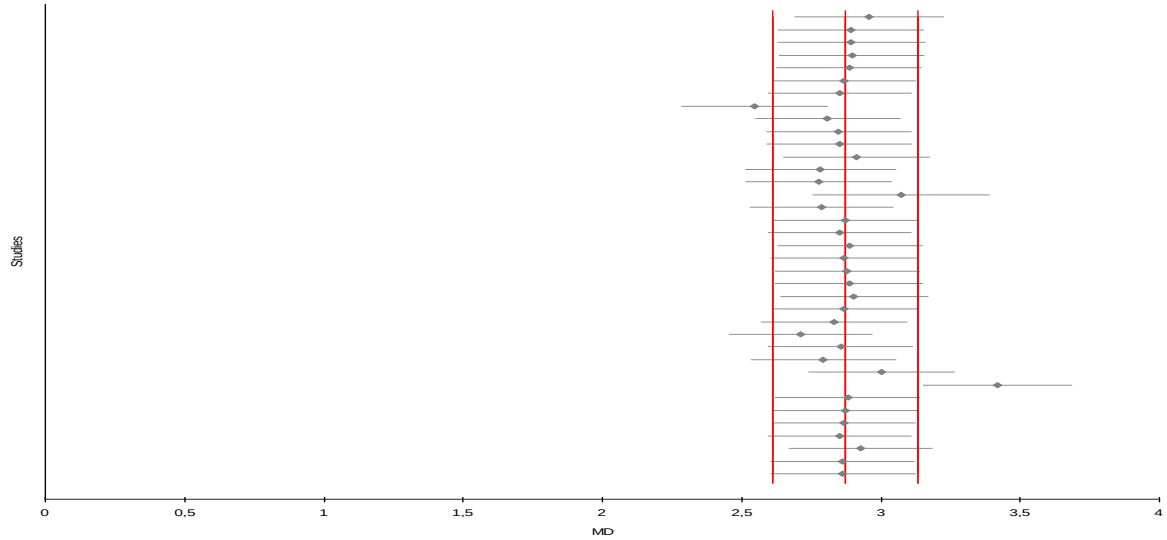

Diagram 3. *Effect Sizes and Rejecting Sensitivity Distribution*

4. Discussion

To analyze the effect of laboratory-based teaching method on students' academic success, the studies which were made from 2000 to 2012 years and compares laboratory-based teaching methods and the other teaching methods. One PhD Thesis and 17 Master Thesis and 12 published articles were chosen for the criteria. This study reveals the alteration effect size of academic success with laboratory-based teaching in science.

Total samples of 30 studies include 1188 students for the experimental group and 1175 students for the control group. To ignore individual differences and bracket perception of subjects who

are in different educational levels such as elementary, high school and college can constitute a problem in terms of study.

The effect size of 30 studies about student's academic success has been determined and calculated as 95% confidence interval and E= +2,8729. It is seen that this value has a huge effect on Thalheimer and Cook's scale. On this basis, it is seen that, laboratory based teaching in science changes positively students' academic success.

5. Conclusions

When combined studies' frequency and percentage values are examined, it is seen that most studies were included with 21,62% ration and 8 studies in year 2007 for this meta-analysis study. This situation shows that most studies which search the effect of laboratory- based teaching in science on student success were conducted in that year.

When looked at combined studies' frequency and percentage values in terms of publication type, it is seen that 17 of 30 studies, namely 56,66%, are master thesis. The insufficiency of PhD thesis numbers in this subject, reveals the need of more these types of studies.

Students' educational levels are separated into three different groups as elementary, high school and college in this meta-analysis study. Elementary and high school cover 40% of all groups with number of 12, when frequency and percentage values are considered. Laboratory based teaching method takes part with a very little level - 20% ration – in college education. This situation reveals that laboratory based teaching method should be used more in college education.

The effect size of the effect of laboratory-based teaching on students' academic success in science, average values of experimental studies and standard deviations were combined with Metamix 2.0 software. As result, Z value was found as 21,5471. With Z=21,5471 value is being significant in the level of p=0,0001, it is of the opinion that studies used in this meta-analysis are homogenous.

Since studies are homogenous, a fixed effect model is preferred and meta-analytic evaluations are made in accordance with this model. According to the result of meta-analysis, the average effect size is found as E= + 2,8729 in p<0,0001 and 2,6116 lower limit and 3,1343 upper limit of 95% confidence interval. With this numeric value, the result is shown up, laboratory-based teaching in science changes positively students' academic success. This value has a huge effect on Thalheimer and Cook's scale.

Meta-analytic effect size forecast can shed light on laboratory-based education in science projects to be planned and implemented. It is thought that, this study might contribute to research literature and lead further studies as a meta-analysis study about efficiency of laboratory-based teaching

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