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The Effect of 7E Learning Cycle on Learning in Science Teaching: A meta-Analysis Study

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Abstract: This article reports the results of a meta-analysis of the effectiveness of 7E learning cycle in science teaching. Totally 35 different effect sizes from 24 experimental studies, comprising 2918 students were included in the meta-analysis. The results confirmed that 7E learning cycle have a positive effect on students' achievement. The overall effect size (Hedges's g) value obtained from independent studies was calculated as 1.245 (% 95 CI, SE = .148) between confidence intervals 956 and 1.534 according to the random effects model. Among all effect sizes 32 had a positive effect whereas 3 of them had negative effect. A number of sub-group analyses (school level, type of publication, subject matter and duration) were conducted. The effect of 7E was not significant for school level, type of publication and duration. However, regarding the subject matter a significant difference was observed. The high effect size calculated in this meta-analysis implies that the 7E learning cycle is a useful strategy that should be included in science curriculums.

Keywords: *7E learning cycle, science teaching, meta-analysis*

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Introduction

Learning cycles and 7E learning cycle

The conduction of a constructivist learning environment in the classroom is considered vital by Oh and Yager (2004), and Tobin (1993). The constructivist theory requires the students to be active in the classroom and during the learning. Constructivist learning is an approach which helps students to acquire new knowledge by using their prior knowledge and develop an idiosyncratic learning method by participating the learning process actively (Özmen, 2004). Shortly, in the constructivist learning approach, knowledge is constructed by the students via participating into the learning process actively and students combine new knowledge with their existing knowledge (Çepni, Ayas, Ekiz & Akyıldız, 2010).

It is an aspiration for science educators to improve students' engagement in the classroom and facilitate the role of the teachers through the use of more effective instructional strategies. It is for many years that science education researchers are trying to develop student-centered instructional strategies (Mecit, 2006). One way to conduct student-centered courses is to use learning cycles which allow instructors to put teaching into a series of planning strategies

All proposed learning cycles in the literature are a consequence of constructivist learning theory which basically asserts that students construct their own knowledge. Learning cycles enables teachers to conduct a series of activities that are meaningful for students and help students to practice for their critical thinking skills (Bevevino et al., 1999). By using the learning cycle students can learn science concepts, fix their incorrect or incomplete knowledge, learn the concepts profoundly, and adapt the learnings gained in school to their daily life (Özbek, Çelik, Ulukök & Sarı, 2012). Using constructivist learning cycle models in science teaching furnishes content of the courses, increases students' attention towards courses, ensures permanent learning, changes students' prejudgments towards science and make courses more entertaining and fruitful (Özalp, 2006).

Several versions of the learning cycles appear in the literature ranging from 3E (Karplus & Their, 1967), 5E (Bybee, 1997), and 7E (Eisenkraft, 2003). Lately, 9E learning cycle (Kaur & Gakhar, 2014) is also proposed. Each ''E'' letter in the learning cycles stands for the capital letters of English words which indicates phases of learning process (Bybee et al., 2006). Starting from 3E, each next cycle of the model is an expansion of the prior model. For instance, 7E cycle differs from the 5E in two ways. The *engage* phase in 5E is expanded into *elicit* and *engage*. Thus, more emphasis is placed on prior understanding and tacit knowledge that can be

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Table 1. Meta-analysis studies conducted on the constructivist learning strategies.

Researchers	Type of constructivist approach	Construct	ES	ES level*
Ayaz (2015a)	5E learning cycle	Attitude	.371	Small
Ayaz (2015b)	Problem based learning	Achievement	1.206	Very large
Ayaz & Söylemez (2015)	Project based learning	Achievement	.997	Large
Ayaz & Şekerci (2015a)	Constructivist approach	Achievement	1.156	Very large
Ayaz & Şekerci (2015b)	Constructivist approach	Attitude	.775	Large
Toraman & Demir (2016)	Constructivist approach	Attitude	.728	Medium
Semerci & Batdi (2015)	Constructivist approach	Achievement	1.075	Large
Semerci & Batdi (2015)	Constructivist approach	Retention	.925	Large
Semerci & Batdi (2015)	Constructivist approach	Attitude	.439	Medium
Anil & Batdi (2015)	5E learning cycle	Achievement	1.132	Very large
Anil & Batdi (2015)	5E learning cycle	Retention	1.417	Very large
Anil & Batdi (2015)	5E learning cycle	Attitude	.552	Medium
Dochy et al. (2003)	Problem based learning	Knowledge	-.223	Small
Dochy et al. (2003)	Problem based learning	Skill	.460	Medium

*According to the classification of Thalheimer and Cook (2002)

used as a basis for the learning to take place. Similarly, *elaborate* and *evaluate* phases are expanded into *elaborate*, *evaluate* and *extend* phases. "The addition of the *extend* phase to the *elaborate* phase is intended to explicitly remind teachers of the importance for students to practice the transfer of learning" (Eisenkraft, 2003, p.59). Finally, Eisenkraft proposed elicit, engage, explore, explain, elaborate, evaluate, and extend discrete elements for the 7E learning cycle and he said "research on how people learn and the incorporation of that research into lesson plans and curriculum development demands that the 5E model be expanded to a 7E model" (p. 56). The primary aim of the 7E learning cycle is to highlight the increasing importance of provoking previous understandings and transferring the concepts to new contexts.

In the *elicit* phase students' prior understandings are prompted and teachers assess any misconceptions the students have. Teachers try to capture the students' attention for the subject matter and examine students' prior knowledge. In this phase, concept cartoons, video-films, animations and simple scientific demonstrations are used to motivate students. In *engage* phase, teachers use a simple experiment or a discrepant event just to capture students' attention, raise questions in their minds and engage them. During the *explore* phase, questioning method is utilized in order to help students explore and revise the subject. Assumptions and hypothesis are established through applying brainstorming within the boundaries of activity related to the subject. Worksheets can be used to guide students and record the data. In the *explain* phase, students try to interpret what they have learnt in the *explore* phase. Teachers can explain the theories, principles, laws and facts with the help of video-film, concept maps or presentations as well as lecturing directly. In this phase, "the teacher guides students toward coherent and consistent generalizations, helps students with distinct scientific vocabulary, and provides questions that help students use this vocabulary to explain the results of their explorations" (Eisenkraft, 2003, p.58). Within the *elaborate* phase, students are encouraged to use their understandings to new areas. This may raise new questions and hypotheses to explore. Students may also solve associated mathematical problems in this phase. Along with formative evaluation summative evaluation is also conducted in the *evaluate* phase on the student learning. Along with the questioning, other ways such as multiple choice, quiz, puzzle, structured grid and true-false questions etc. can be applied to evaluate students learning. In the *extend* phase students transfer their learning to a new context. Thus, students are expected to extend and expand their understandings to everyday life experiences.

Many researches in the area of science teaching, have reported positive effects of 7E learning cycle on students' achievement and skills. (Bülbül 2010; Damar, 2013; Demirezen, 2010; Gök, 2014; Gürbüz, 2012; Kanlı, 2007; Naluan Phatthalung & Kattiyamarn, 2012; Paramita, Sudhita & Dibia, 2013; Polyiem, Nuangchalerm & Wongchantra, 2011; Shaheen &

Kayani, 2015; Saraç, 2015; Şahin, 2012; Taguiam, 2015; Toroslu, 2011; Yenice, 2014). The usage of 7E learning cycle in science courses increases students' academic and conceptual achievement more efficiently since the model give students the chance to explore. Moreover, since the phases of the model are clear effective learning takes place. Besides, the 7E learning cycle can be time-consuming because of the fact that each phase should be carried out meticulously (Şadoğlu & Akdeniz, 2015).

7E learning cycle in Turkey

Since 2013, Turkish National Education Ministry has grounded the science curriculum on the research-oriented and inquiry-based learning approach (National Education Ministry, 2013). In the current science curriculum, the student-centered teaching which is the basis of the constructivist learning approach has been employed. In other words, the new science curriculum is based on a strategy in which students are able to participate in the class discussions actively and provided with the opportunity of constructing new knowledge on their previous knowledge. The emphasis of the constructivist approaches such as problem based and project based learning, 5E and 7E learning cycles in the national science curriculum increased the interest of the researchers in this area. Since sufficient studies appeared in the last decade several meta-analysis regarding the effect of constructivist methods on students' learning and attitudes were conducted by Turkish researchers. The list of the meta-analysis, with key characteristics, conducted in the last 13 years are presented in Table 1.

As in indicated in Table 1, no meta-analysis related to 7E learning cycle are studied. Therefore, it is expected that this study will make contributions to the literature.

The purpose of this research was to synthesize the results of the studies that were performed to identify the effect of 7E learning cycle on students' learning in science teaching. Following research questions were determined for the meta-analysis:

1. Does learning with 7E learning cycle impact students' achievement at K-12 and K-16 level?

2. Does the effect of 7E learning cycle on students' achievement vary according to publication type, school level, subject matter and the duration of the intervention?

Methodology

Research Goal

This meta-analysis quantitatively combined the findings from the primary studies on the effect of the in-class use of 7E learning cycle on the achievement of students at different grade levels including university students.

Dependent and independent variables: The effect sizes calculated for the outcome of 7E learning cycle on student achievement were the dependent variable and teaching method (7E learning cycle versus traditional teaching) was the independent variable of this meta-analysis.

Publication Bias: Classical fail-safe N test, which estimates the amount of studies with non-significant effects that are required to bring the significance finding to p = .05, was conducted to assess whether the findings were biased. Additionally, to visually observe publication bias a funnel plot was also presented.

Data Collection

Literature search: To search pertinent studies we used several search strategies. First, we examined available PhD theses in online database of Turkish National PhD theses Center (TNDC). We used the keyword 7E and its variations (7e learning model, 7e learning cycle model, 7e instructional model, 7e instructional cycle model and 7e learning cycle) along with the linking terms learning, achievement and performance. Since TNDC enables to search both in Turkish and in English we searched the database in both languages with the same translated key words. The TNDC database has no date restriction, it displays all relevant studies provided however that one should register. This search yielded 8 PhD theses and 6 master theses. Second, we searched key journal databases in Turkey, including ASOS, Dergi Park Akademik, Google Academic, and ULAKBİM. Same Turkish and English versions of the key terms were used to conduct this search and afterwards 4 articles were included to meta-analysis. Third, we searched the following databases in order to locate the international studies: Academic Search Complete, Elsevier, Science Direct, ERIC, Google Scholar, ProQuest Desertions and Thesis, and Web of Science. In this search 6 more articles were found after screening processes. Fourth, we gone over the references of all studies included in order to detect further published studies and found two articles. Finally, for studies with inadequate statistics, we sent e-mails to six researchers. Among them 3 supplied required statistics. Totally 24 studies which produced 35 effect sizes were determined after all these efforts of literature search. The search was completed in March 2016.

Inclusion Criteria: A two-phase screening process was conducted for the selection of the studies. Phase I was the screening of headings and abstracts while in Phase 2 full papers were screened. In order to include a study following criteria had to meet: (a) have a measure of students' achievement; (b) had to be written in either Turkish or English; (c) had to be published between 2006-2015; (d) had to employ an experimental or quasi-experimental design; (e) provide sufficient information to calculate effect sizes; (f) had to be conducted in science subjects; (g) had to used 7E learning cycle to increase student achievement.

Coding Process: Initially a coding form was developed by the researchers to collect relevant data from publications. Then, all eligible studies that provided the selection criteria was coded for the grade level, sample size, year of publication, publication type (e.g., article and thesis), subject matter, contact hours, study design, country, and statistics such as mean and standard deviations. Two independent raters coded all selected studies for descriptive and statistical values along with key study features reported. When coding was compared they achieved an inter-rater agreement of .90. Any uncertainties or problems about eligibility were fixed through one-to- one dialog, and 100 % agreement was achieved.

Data analysis

Homogeneity: To determine whether the results shared a common effect size in the population or whether the set of effect sizes differ statistically significantly, homogeneity statistics were used for the collected effect sizes. Depending on the insignificance or significance of the Q statistics either a fixed-effects model or a random-effects model would be used for data analysis. The fixed effects statistical model assumes the distribution of effect sizes around their mean is less than or equal to the estimated sampling error. Conversely, the random effects statistical model assumes heterogeneity of population effects, given that the associations between 7E learning cycle and student achievement differ among studies.

Calculating Effect Sizes: Effect size, standardized mean difference, is a simple way of computing the difference between the means of two groups. We calculated the effect sizes in terms of Hedges's g which provides a better estimate of the population variances, especially the smaller the sample sizes. We used the CMA 2.0 software to conduct the analysis. Some studies reported sample size, mean and standard deviation, while some other studies reported statistics in the form of p value, t value and F value. Hopefully, CMA calculate the effect sizes depending on different data entries.

Each primary study contributed one effect size, unless it includes independent samples. If studies reported effect of 7E learning cycle on achievement of different groups, more than one effect sizes were calculated for these studies. For example, Saraç's (2015) study included two independent samples of middle school students; hence it supplied two effect sizes in the total estimation. Independent effect sizes were then weighted based on the each study's sample size and standard error. That is, studies conducted with greater sample sizes were given more weight.

After finding the common effect size, the retrieved studies were clustered to analyze differences in the average effects among groups. For instance, for the course effects, studies reporting separate data on different subjects (biology, chemistry, physics and science) were combined to evaluate this sub-group analysis.

Results

Totally 35 different effect sizes from 24 experimental studies, comprising 2918 students (control group=1488 students and experimental group= 1430 students), were added to the meta-analysis. The obtained effect sizes were grouped according to type of publication: PhD theses (16), master theses (8), and articles (11). Similarly, they were congregated according to subject matter: biology (4), chemistry (2), physics (16), and science (13). Additionally, they were aggregated according to grade level: middle school (12), high school (19) and university (4). Finally, they were grouped according to the duration of the intervention: long (13), short (13) and blank (9). Most of the studies (%77) used achievement tests to measure students' learning, and amongst these studies, 88 % reported Cronbach's alpha bigger than .75. The included studies are presented in appendix I with key characteristics.

Main Effect Size Analysis

The standardized mean difference can be calculated in several ways. One of them is the Cohen's d (1988), which is based on the difference between means of the groups, divided by the pooled standard deviation of these groups. The Cohen's d (1988), which is based on sample averages, especially for small samples, results in a biased estimate of the population effect size (Hedges and Olkin, 1985). Since in this meta-analysis the average sample size per study was around 41, we used Hedges's g for the effect size measure.

Table 2 shows effect size, degrees of freedom, 95%confidence intervals and some other statistics for fixed and random effect models. The overall effect sizes for fixed and random effect models were .989 and 1.245 respectively and were considered to have large and very large magnitudes (when converted to Hedges's g) according to Thalheimer and Cook's (2002) guidelines. The overall positive effect size indicates a positive effect of 7E learning cycle on student

Table 2.Fixed and random effect model statistics

Model	**ES**	**df**	**(Q)**	**SE**	**z**	**p**	**I^2**	**%95 confidence intervals**	
								Lower Limit	**Upper Limit**
Fixed	.989	34	430.93	.041	24.39	.00	92.11	.910	1.069
Random	1.245			.148	8.43	.00		.956	1.534

Study name	Statistics for each study						
	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Saraç, 2015-1	1,250	0,318	0,101	0,628	1,873	3,935	0,000
Saraç, 2015-2	0,651	0,298	0,089	0,068	1,235	2,188	0,029
meydan, 2015	0,308	0,382	0,146	-0,441	1,057	0,805	0,421
Kanlý, 2007-1	0,727	0,228	0,052	0,280	1,173	3,190	0,001
Kanlý, 2007-2	0,088	0,221	0,049	-0,345	0,520	0,397	0,692
Avcýoglu, 2008	2,201	0,317	0,100	1,580	2,822	6,946	0,000
Bulbul, 2010-1	2,348	0,318	0,101	1,725	2,971	7,388	0,000
Bulbul, 2010-2	2,312	0,316	0,100	1,693	2,931	7,321	0,000
Demirezen, 2010-1	0,601	0,265	0,070	0,081	1,120	2,267	0,023
Demirezen, 2010-2	2,459	0,345	0,119	1,783	3,136	7,122	0,000
Bulut, 2012	1,955	0,228	0,052	1,509	2,401	8,585	0,000
gurbuz, 2012	3,953	0,510	0,260	2,954	4,952	7,755	0,000
Yenice, 2014	1,971	0,302	0,091	1,379	2,564	6,522	0,000
gok, 2014-1	0,545	0,152	0,023	0,247	0,843	3,583	0,000
gok, 2014-2	0,160	0,150	0,022	-0,133	0,454	1,069	0,285
gok, 2014-3	0,529	0,153	0,023	0,228	0,829	3,449	0,001
çekilmez, 2015	1,108	0,260	0,068	0,599	1,618	4,266	0,000
Toroslu, 2011-1	0,967	0,216	0,046	0,544	1,389	4,485	0,000
Toroslu, 2011-2	0,585	0,139	0,019	0,313	0,857	4,218	0,000
Y. Damar, 2013-1	2,494	0,262	0,068	1,982	3,007	9,533	0,000
Y. Damar, 2013-2	1,764	0,181	0,033	1,408	2,119	9,717	0,000
Dogan, 2011-1	1,163	0,325	0,106	0,525	1,800	3,575	0,000
Dogan, 2011-2	0,705	0,329	0,109	0,059	1,350	2,138	0,032
Dogan, 2011-3	0,834	0,352	0,124	0,145	1,523	2,371	0,018
Balým, 2008-1	0,969	0,377	0,142	0,231	1,707	2,573	0,010
Balým, 2008-2	-0,049	0,355	0,126	-0,746	0,647	-0,139	0,889
Kunduz, 2013	0,581	0,215	0,046	0,161	1,002	2,708	0,007
Baybars, 2014	1,920	0,280	0,078	1,371	2,469	6,854	0,000
Baybars, 2015	2,758	0,345	0,119	2,081	3,435	7,985	0,000
Pramita, 2013	1,747	0,301	0,090	1,158	2,337	5,809	0,000
Naqeeb, 2015	1,474	0,203	0,041	1,076	1,872	7,256	0,000
polyiem, 2011	-0,473	0,243	0,059	-0,950	0,004	-1,945	0,052
Naluan, 2012	-0,205	0,256	0,065	-0,705	0,296	-0,800	0,424
Nurmalasari, 2015	0,730	0,180	0,032	0,378	1,082	4,065	0,000
Taguiam, 2015	3,586	0,393	0,154	2,817	4,356	9,134	0,000
	1,245	0,148	0,022	0,956	1,534	8,433	0,000

Hedges's g and 95% CI

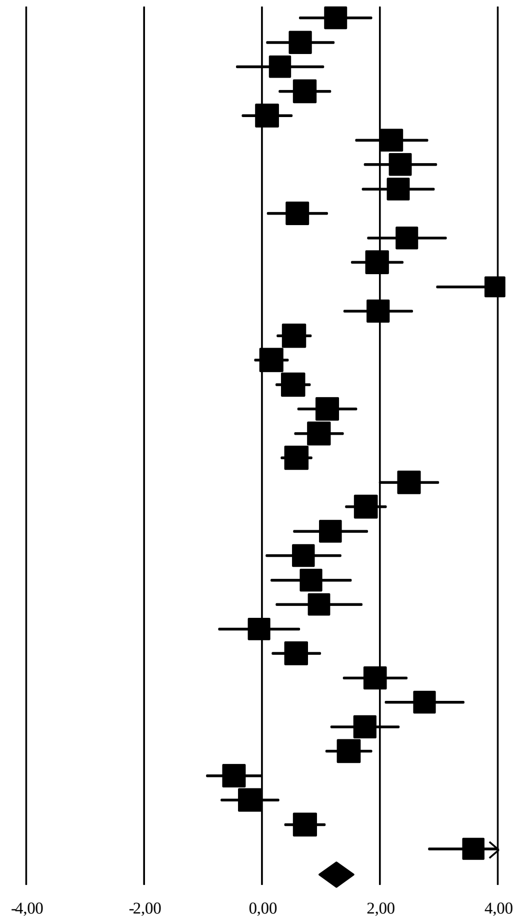

Figure 1. The Distribution of the effect sizes

achievement. Furthermore, the significant Q statistic result, $Q(34) = 430.93$ $p < .05$, shows a heterogeneity of effect sizes, suggesting the need to use random effect model for subsequent analysis.

The distribution of the effect sizes of the 24 studies is shown in Figure 1. This figure shows a synthesis plot with a point estimate of the individual effect size (symbolized by the square), and its confidence intervals (symbolized by the horizontal line across the square). As seen in figure, for two studies (Gürbüz, 2012 and Taguiam, 2015) the upper confidence interval limits exceeds the +4 boundary. The size of the square in the middle of the line representing the confidence interval is approximately the same for all studies, suggesting almost equal weight per study. In other words, the contribution to the overall effect size from each study is roughly equal. The overall estimated effect size and 95 % confidence intervals are represented by the center and the width of the diamond, respectively.

Among the effect sizes presented in Figure 1 Polyiem's (2011) study had the lowest (-.473) effect size and that of (Gürbüz, 2012) had the largest effect size (3.953). Meanwhile, among all effect sizes only three of them were negative (Balım, 2008-2; Naluan, 2012; Polyiem, 2011).

Publication Bias Evaluation

To see whether there is publication bias we constructed a funnel plot (Figure 2), which helped a visual indication for the publication bias. The scatterplot formed almost asymmetric funnel, showing no potential bias.

To further examine the possibility of publication bias we performed the classic fail-safe N analysis to locate the number of studies with non-significant results needed to bring the significant level down to p = .05. As suggested by the data in Table 3 an additional 6327 lost studies with an average zero effect size would be required in order to nullify the effect size. Overall, these results indicated that publication bias could not explain the significant positive outcomes detected across all studies.

Table 3. Results of the classic fail-safe N.

Z-value for observed studies	26.42
P-value for observed studies	.00
Alpha	.05
Tails	2.00
Z for alpha	1.96
Number of observed studies	35
Number of missing studies that would bring p-value to > alpha	6327

Sub-group Analyses

To learn more about the effect of 7E strategy on student achievement this study run analyses for four different subgroups: publication type, subject matter, educational level and duration (contact hours). The collected individual effect sizes may have significantly different averages when grouped according to publication type (PhD thesis, master thesis and article). However, as seen in Table 4, no significant heterogeneity in effect sizes among the three groups was found, Q_B (2) = .128, $p > .05$. We also grouped the effect sizes according to subject matter and found 4, 2, 16, and 13 studies for biology, chemistry, physics, and science subjects respectively. The between-group comparison was significant for this grouping, (Q_B (3) = 11.885, $p < .05$) indicating that the effect sizes differed significantly among the subjects. Where chemistry subject had the maximum (2.066) and science subject had the minimum (1.002) group averages. Based on school level category, the overall effect sizes were disaggregated and regrouped into three school level (i.e., middle, high school and university). The three groups showed non-significant effect size differences.

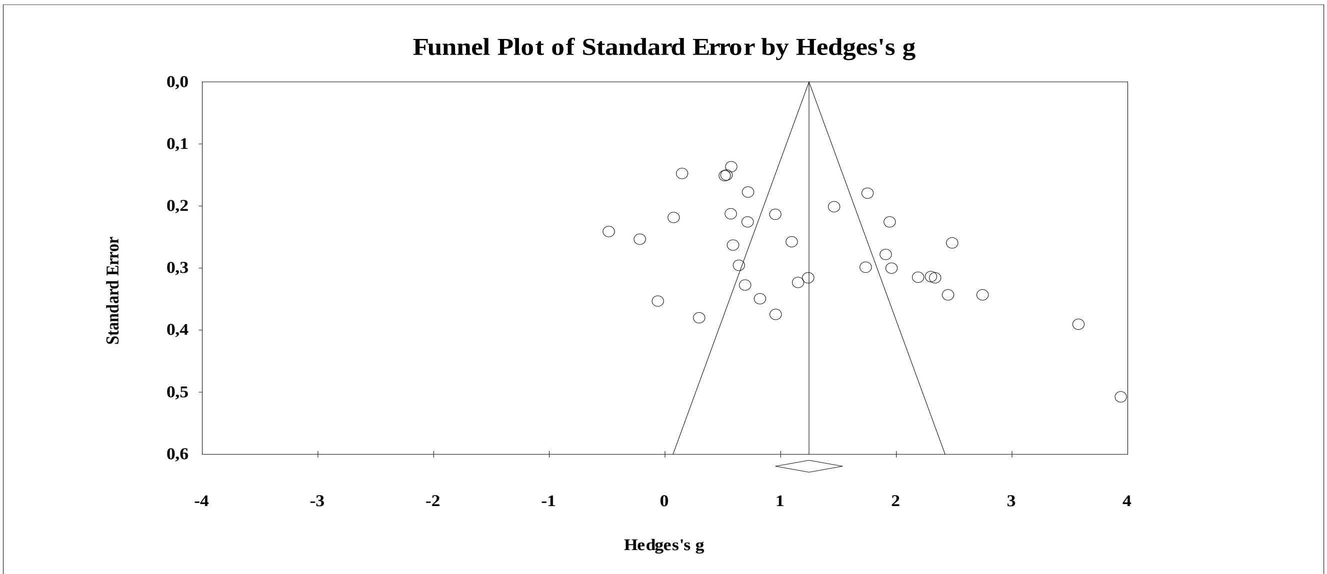

Figure 2. Funnel plot

Table 4. Sub-group analysis statistics

Sub-group	(Q_B)	p	N	ES	%95 CI		SE
Publication type	.128	.938			**Lower**	**Upper**	
Article			11	1.165	.528	1.803	.106
Master thesis			8	1.307	.848	1.765	.055
PhD thesis			16	1.277	.870	1.683	.043
Total			35	1.267	.992	1.541	.020
Subject matter	11.885	.008					
biology			4	1.973	1.554	2.392	.214
chemistry			2	2.066	-.879	5.011	1.502
Physics			16	1.150	.743	1.558	.208
Science			13	1.002	.557	1.447	.227
Total			35	1,472	1.146	1.633	.124
School level	2.847	.241					
Middle school			12	.919	.477	1.360	.225
High school			19	1.419	1.031	1.807	.198
University			4	1.351	.253	2.449	.560
Total			35	1.211	.929	1.493	.144
Duration	2.287	.242					
Long(≥20 hours)			13	.992	0.583	1.401	.209
Short(<20 hours)			13	1.613	1.010	2.215	.307
Blank			9	1.120	.584	1.656	.274
Total			35	1.168	.882	1.454	.146

p<.05

The between group comparison was not significant, Q_B (2) = 2.847, p > .05, indicating no differences in the magnitude of the means of the three educational level groups. Table 4 presents the sub-groups and their corresponding statistics. Finally, the studies found for this meta-analysis were examined according to the duration of the intervention; that is the contact hours with students during 7E activities. Nine studies (13 effect size) lasted 20 hours or more were accepted as long duration and 11 studies (13 effect size) were accepted as short duration. Since 4 studies (9 effect size) did not report the duration they were grouped as blank. Even though the mean effect size of small duration was higher than that of long duration, the chi-square analysis indicated insignificant differences among long and short durations of 7E applications.

For type of publication more studies were published as PhD thesis (46%) than articles (31%).For the domain subject, physics subject was the most widely studied of the 7E learning cycle (46%), followed by science subject (37%). For the school level the largest proportion of studies involved the high school (54%); the next largest group was middle school (34%). For duration, 26% of the studies did not report the duration and equal number of studies (37%) employed long and short durations during the 7E interventions.

Discussion and Conclusion

In total there were 24 experimental study on the use of 7E learning cycle as strategy in educational interventions, 35 effect sizes, and 2918 participants. Analysis of the effect sizes of studies published as theses and articles in peer-reviewed journals have revealed that the overall effect of using 7E learning cycle in classrooms is positive, with a very large effect size of 1.245. This meta-analysis indicates that most of the research on 7E strategy is done in Turkey. This may be because of the adaptation of constructivist approach into science curriculum in Turkey since 2005-2006 school year (Terzi, 2011). Additionally, almost all meta-analyses in this area are also conducted in Turkey (see Table 1).

Through the analysis of sub-groups, we found that 7E learning cycle has been used in many different school levels and domain subjects. Moreover, they have been published for different purposes (PhD thesis, master thesis and article) and have used different durations of 7E activities to try to make a difference between comparison and experimental groups. The effect of 7E was not significant for school level, type of publication and duration. However, regarding the subject matter a significant difference was observed. Among all domain subjects the smallest effect was observed in science (a middle school course). The possible reason may be the complexity of 7E strategy for relatively small age students and it is difficult for those students to follow the steps when compared to higher age students. On the other hand, the largest effect size was calculated for chemistry indicating the more successful use of 7E strategy in this course. However, since there were only two studies for chemistry sub-group, the calculated average effect size may be misleading. That is why, we disregarded the chemistry and choose the biology course for which the 7E learning strategy is most applicable. These findings will contribute to a better understanding of which educational level, how long and in which subject the use of 7E in the learning setting will be more effective.

An interesting finding in this meta-analysis was the correlation between the durations of the 7E strategy and the effect sizes. According to Cohen's (1998) classification a negative insignificant (r = -.288, p = .158) correlation was found. The durations for the usage of the 7E strategy varies between 9 hours to 36 hours. We divided these durations into two groups where 20 hours was the frontier point. Sub-group analysis exposed that there was no significant variance between long (.992) and short (1.613) applications of 7E strategy. This unexpected result needs further investigations. The average very large effect size value obtained from those short interventions of 7E strategy should be questioned. For locating reliable results long-term teaching interventions are essential (Hsieh et al., 2005; Pressley & Harris, 1994), however in this meta-analysis it was found that long-term applications of 7E strategy did not necessarily yielded better effects. Similar unexpected results regarding the duration was found in other meta-analysis. For instance, the meta-analysis conducted on the effect of the in-service training course on student achievement (Balta, Arslan & Duru, 2015; Blank & Alas, 2010; Yoon, et al., 2007) yielded counterintuitive results in terms of the relation between duration and the effect size. Similarly, this finding is consistent with those of Kulik and Kulik (1991), and Sung, Chang and Liu (2016) who found that shorter applications of teaching had greater outcome in computer-based instruction.

The fact that students more quickly involved in the activity when they are novel may be a reason for why short-term applications of 7E have more effects. Also, long term interventions may bore students and prevent them to prepare for their lessons and exams. "In terms of the interventional supports, in most short-term studies, researchers could gather all of their resources for one shot", so they chose the most suitable 7E activities, "prepared more elaborate learning activities, and made every effort to control confounding factors" (Sung, Chang & Liu, 2016, p. 264).

Several meta-analysis appear in the literature on the teaching strategies of constructivist approach. Ayaz (2015a) has investigated the effect of 5E learning strategy on the students' attitudes towards the subjects they learn. His meta-analysis yielded a small effect size (.371) according to the classification of the Thalheimer and Cook (2002). Our results leads to that of Ayaz. However, it should be interpreted cautiously because the constructs (achievement versus attitude) in the two studies are different. In other saying, the effect of 7E learning cycle on the students 'achievement is very large while that of 5E on students' attitudes is small. Moreover, in his another meta-analysis Ayaz (2015b) tried to find a relation between problem based learning and students' achievement. There is a good fit between ours and Ayaz's results regarding the effect sizes; 1.245 and 1.206 respectively. What increases the relationship between the two studies is that both are strategies of constructivist approach and both have found similar effects of the teaching strategies of constructivism on the students' achievement. Furthermore, there is a similarity between our meta-analysis and that of Ayaz and Söylemez (2015) where they conducted the study on the effect of project based learning on students' achievement. This is also a teaching strategy of constructivist approach and has a large effect (according to Thalheimer and Cook) on students' learning (d=.997). Additionally, the meta-analysis on the effect of constructivist learning on students' success and separately on the attitudes of students was conducted by Ayaz and Şekerci (2015). They found an overall effect size of 1.156 for the achievement and .775 for the attitude. Moreover, Toraman and Demir (2016) in their meta-analysis on the effect of constructivism on attitudes towards lessons calculated an overall effect size of 0.728. Their finding is similar to that of Ayaz and Şekerci (2015) who found an effect size of .775 for the attitudes of students towards the use of the problem-based learning approach in science lesson. Furthermore, Semerci and Batdi (2015), and Anil and Batdi (2015) separately collected the studies related to constructivist approach and 5E learning cycle on students achievement, retention and attitudes. In terms of achievement, the results of both studies are good agreement with our results (1.075 and 1.132 respective effect size values for achievement). Finally, the results of the Dochy et al. (2003) is nearly completely different from all aforementioned studies. For clear comparison of all these meta-analysis Table 1 can be examined. What is striking is that in all these meta-analysis, the effect of constructivist learning strategies on students' achievement is higher than the effect on the attitudes of the students.

Implications and Suggestions

The effect sizes, displaying the effectiveness of 7E learning cycles, are distributed in a wide range between -.473 and 3.586 according to Hedges's g. This distribution indicates that the effectiveness of 7E strategy may be quite different.

This study found that 7E strategy can enhance educational effects, however, the inconsistency between the effect sizes and the durations suggests more elaborate 7E intervention designs to more comprehensively exploit the educational benefits.

Since the effect of 7E strategy is so high, teachers should be encouraged to incorporate this strategy into their teaching, and to gradually customize it into their own personalized teaching style. Moreover, the high effect of 7E indicated by 24 primary studies is an indicator of a successful decision of government that had decided to incorporate a constructivist approach into curriculum in all levels and subject in K-12 schools in Turkey. Furthermore, to ease the moving the researchers' findings related to the effectiveness of 7E strategy to school teachers, it will be useful to include university-level researchers as counselors in in-service training course.

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Note. References marked with an asterisk indicate studies included in the meta-analysis

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APPENDIX I

Author	Year	Country	Course	Grade level	Duration (hours)	Publication type	# of ES
Hakan saraç	2015	Turkey	Science	5th grade	20	PhD thesis	2
A. Mesude meydan	2015	Turkey	Science	7th grade	24	Master thesis	1
Uygar kanlı	2007	Turkey	Physics	University	32	PhD thesis	2
Orçun Avcıoğlu	2008	Turkey	Physics	10th grade	12	Master thesis	1
Yeter bülbül	2010	Turkey	Biology	9th grade	12	PhD thesis	2
Selçuk Demirezen	2010	Turkey	Physics	11th grade	21	PhD thesis	2
Hüseyin Bulut	2012	Turkey	Biology	10th grade	12	Master thesis	1
Fatih Gürbüz	2012	Turkey	Science	6th grade	12	PhD thesis	1
Elif Yenice	2014	Turkey	Science	8th grade	16	Master thesis	1
Gülsüm gök	2014	Turkey	Science	6th grade	24	PhD thesis	3
Sıdıka Çekilmez	2015	Turkey	Physics	10th grade	12	Master thesis	1
Seda Ç. Toroslu	2011	Turkey	Physics	10th grade	16	PhD thesis	2
Sevda Y. Damar	2013	Turkey	Physics	10th grade	36	PhD thesis	2
Ali G. Balım	2008	Turkey	Science	7th grade	12	Article	2
Nazan Kunduz	2013	Turkey	Chemistry	10th grade	NA	Article	1
Meryem Baybars	2014	Turkey	Science	University	3	Article	1
Meryem Baybars	2015	Turkey	Physics	University	32	Article	1
D. M. W. Paramita	2013	Indonesia	Science	6th grade	NA	Article	1
Muhammed Naqeeb	2015	Pakistan	Biology	9th grade	24	Article	1
Titiworada Polyiem	2011	Australia	Physics	9th grade	18	Article	1
Nuttaka Naluan	2012	Thailand	Science	6th grade	NA	Article	1
Resky Nurmalasari	2015	Indonesia	Physics	11th grade	NA	Article	1
Andrelyn Taguiam	2015	Philippines	Chemistry	10th grade	9	Article	1
Aydoğan Doğan	2011	Kyrgyzstan	Physics	9th grade	NA	Master thesis	3