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The Effect of Inquiry-Based Learning on Academic Success: A Meta-Analysis Study

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ABSTRACT

Inquiry Based Learning (IBL) is a student-centered strategy within the constructivist learning approach. This strategy is an important approach that makes students active inside and outside the classroom, and enables students to work in groups, conduct research, present their research, and increase their academic success. When the literature is reviewed, there are many studies that show that IBL increases the academic success of students. The aim of this study is to make the meta-analysis of articles and theses carried out in Turkey between the dates of 01.01.2000 and 01.03.2020 that investigate the impact of IBL on the academic achievement. In this study, meta-analysis method was used to determine the effects of IBL on students' academic achievement based on grade levels and publication types. The studies evaluated within the scope of this study were created by using the databases of Google Scholar and the National Thesis Center of the Council of Higher Education. To this end, 30 studies were selected in accordance with year, method, data, and publication type criteria. In this study, the thesis and article evaluation form developed by the researchers was used as the main means of data collection. Comprehensive Meta-Analysis (CMA) program was used to analyze the data. According to the results of this study, it is concluded that IBL significantly increases the academic achievement and the effect sizes are meaningful when grade levels are compared. That is, IBL at high school level is more effective than other educational levels, and when the effect sizes are examined, there are no significant differences based on the types of publication (i.e., articles and theses).

Key words: Academic Achievement, Inquiry-Based Learning, Meta-Analysis, Effect Size

INTRODUCTION

The word 'inquiry' is defined as the task of questioning in the Current Turkish Dictionary of Turkish Language Association (TDK, 2020) and questioning is the act of inquiring those who might be related to a criminal problem. Inquiry, according to Kartal (2014), is a versatile activity that includes examining books and various sources of information to ask questions and make observations and pre-evaluations. Güneş (2014) defines inquiry as a means of creating changes in the mental structure and mental skills of individuals and enabling students to develop their thinking and decision-making skills, understanding and using information, and not just directly transferring information. Based on these definitions, it can be stated that the competency of inquiry is an important skill that students at all educational levels should acquire. In line with these explanations, it is important to define and understand the Inquiry Based Learning (IBL) strategy.

When the literature is reviewed for the purpose of this study, many studies have emerged on the effects of IBL on academic achievement carried out in Turkey (Abdi, 2014; Akpullukçu, 2011; Altunsoy, 2008; Bailey, 2018; Bilir & Özkan, 2018; Çakar, 2013; Çakar et al., 2014; Çalışkan, 2008; Çelik, 2012; Çelik & Çavaş, 2012; Duban, 2008; Ebren Ozan, 2018; İlter, 2013; İnal, 2013; Kaçar, 2020; Kaya & Yılmaz, 2016; Keçeci & Yıldırım, 2017; Parim, 2009; Tatar, 2006). The purpose of this study is to implement the meta-analysis of dissertations and articles, which investigated the effect of the IBL on the academic achievement of students in Turkey between 01.01.2000 and 01.03.2020. In this direction, one of the sub-objectives of this study is to determine whether the effect size of IBL on the academic achievement has a significant effect based on different educational levels and the types of publication (articles-dissertations). With this study, it is thought that evaluating the studies conducted on the effect of IBL on academic achievement with a holistic perspective will constitute an important resource for the stakeholders of education. With this study, it is also important to find out the significant effect sizes of IBL on the academic achievement of students. Furthermore, finding only one meta-analysis study about the effect of IBL on academic achievement in the literature study shows the need for this study.

According to Kurudayıoğlu and Tüzel (2010), the concept of literacy has been conceptualized as a skill required

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by the age since the expectations and values of society show a different feature in every age and social acceptance and meanings can change according to the characteristics of the age. In this sense, it is possible to define information literacy as an effort to transform written or visual/electronic information into the structured information by selecting and classifying (Kurudayıoğlu & Tüzel, 2010). According to Aytaş and Kaplan (2017), "Starting from the recent past, the concept of literacy necessitates a more detailed and target-oriented study about the field to be literate" (p. 293). In line with these explanations, it can be stated that the application of IBL in learning environments will increase the academic achievement of students and improve their knowledge, internet, electronic, critical, and scientific literacy.

LITERATURE REVIEW

In this sense, according to Güneş (2014), IBL is one of the strategies within the constructivist learning approach. It provides an environment that students can determine and ask valid and testable questions; determine hypotheses and alternatives; gather information; and apply, evaluate, analyze, and interpret scientific methods and techniques (Kartal, 2014). Hırça (2014) considers IBL to be one of the most effective ways in which students can take an active role in the classroom, become aware of the problems around them, produce different solutions to these problems, and continue the learning process more efficiently. Moreover, Çalışkan (2017) defines IBL as an approach where the teacher presents a complex situation to the students so that they can try to solve these problems by collecting information and testing the results. Sözen (2010), on the other hand, defines IBL as a method where the learner is at the center and makes it possible to solve problems with significant questions and critical thinking.

Studies show that IBL increases the academic achievement of students not only in science classes but also in areas such as arts, foreign languages, social studies, and mathematics (İlter, 2013). In this context, according to Cairns and Areepattamannil (2019), there are generally five basic features of IBL, regardless of a grade level:

1- Asking scientifically oriented questions to keep students busy.
2- Providing evidence that enables students to develop and evaluate their explanations on scientifically oriented questions.
3- Providing explanations that students develop from evidence to address scientifically oriented questions.
4- Evaluating the expressions that reflect the scientific understanding that may contain alternative explanations.
5- Communicating the proposed explanations and justifications.

According to Karamustafaoğlu and Havuz (2016), IBL aims to find solutions to the problems faced by individuals and to develop mental skills by directing individuals to meaningful learning. Ernst et al. (2017) define IBL as a form of active learning that occurs in many shapes and sizes. According to Lee and Songer (2003), IBL is a teaching approach that enables students to understand the process of producing scientific knowledge while they learn and witness the process. IBL enables students to understand the act of learning by making students active in the courses. Students use scientific process skills by researching problems as a group. Students also engage in collaborative activities in this strategy. In this way, learning becomes fun and enjoyable. IBL also requires students to use technology to carry out general network (Internet) research and present them. Based on these explanations, students can learn to do research and investigation by using technology more actively. In the literature, there are studies showing that IBL increases the academic success of students, the permanence of learning, and improves many skills.

METHOD

When the literature is reviewed, there are several studies carried out in Turkey (Bailey, 2018; Bilir & Özkan, 2018; Kaçar, 2020; Keçeci & Yıldırım, 2017) that investigated the effect of IBL on academic achievement. However, calculating a general effect size by combining results from various studies can enable us to see the effect of IBL on academic achievement more broadly. The meta-analysis method was used in this study which investigates the experimental studies implemented for the impact of IBL on the academic achievement and calculates the general size of efficiency and possible differences due to sub-groups. Meta-analysis refers to a set of statistical procedures used to quantitatively collect the results of multiple studies to arrive at a general conclusion (Şen & Yıldırım, 2020). By means of meta-analysis, the results of multiple studies are combined with numerical methods and thus an overall judgment can be obtained. At the same time, the meta-analysis approach provides researchers with summative and comprehensive information about multiple studies (Gliner et al., 2015).

Inclusion and Exclusion Criteria

We have reviewed articles and dissertations about IBL carried out in Turkey for this study. While the articles were searched from the Google Scholar database, dissertations were reviewed in The Council of Higher Education National Dissertation Center database. The studies to be included in this present study were selected according to the criteria determined by the researchers based on the literature review regarding the subject. The criteria for the studies to be included in the study were:

1- The study should be conducted in Turkey between the dates 01.01.2000 and 01.03.2020.
2- The study should be a quasi-experimental study with pre-test and post-test groups.
3- The study should contain the statistics needed to calculate the effect size.
4- The study should consist of articles and dissertations.
5- If a study is published as both a dissertation and an article, the dissertation is included in the work.

As a result of the literature review implemented according to the criteria above, 35 studies were obtained. Three studies were excluded from the study due to the lack of data,

and two studies because of extreme values that would disrupt publication bias. Finally, 30 studies were included in the analysis. The diagram showing the inclusion processes of these studies in the research is shown in Figure 1.

Descriptive statistics about the studies included in meta-analysis were presented in Table 1. Five of these studies were conducted at the higher education level, five at the high school level and 20 at the secondary school level. Furthermore, 23 of these studies consist of dissertations, while 7 of them are articles.

The Analysis of Data

First of all, a data entry table was created by the researchers so that the works to be included in the study could be coded correctly. In this table, the headings containing the information needed to calculate the effect size such as the year the research was published, sample, sample sizes, mean, and standard deviation were included. In this study, research data were coded by two researchers to obtain more valid and reliable results. As a result of the coding, it has been revealed that there is a complete agreement between the coders. After the coding phase was completed, the data obtained were analyzed with the Comprehensive Meta-Analysis (CMA v.2; Borenstein, Hedges, Higgins, & Rothstein, 2005) program. Then, the effect sizes obtained from the standardized mean differences of each individual study and the overall effect sizes were calculated. There are 3 types of effect sizes used as standardized mean difference in meta-analysis studies; Cohen's d, Hedges's *g*, and Glass's delta. The classification of Cohen (1988) was used in the interpretation of the effect sizes. According to this classification: Cohen's $d < .20$ indicates an insignificant effect; $20 \leq$ Cohen's $d < .50$ is a low level effect; $.50 \leq$ Cohen's $d < .80$ is a medium effect; and Cohen's $d \geq .80$ is a high level of effect (Cohen, 1988). Since some sample sizes used were below 20, Hedges's *g* was used in this study, which performs better than Cohen's *d*, (Lipsey & Wilson, 2001).

In addition, publication bias is also an important factor for valid results based on a meta-analysis study. In this context, Egger's test, Duval and Tweedie's trim and fill test, and Begg's test were performed and examined in the funnel plot before moving on to the findings related to the sub-problems of the research. Descriptive information about the studies included in this study is given in Table 1.

In line with the information in Table 1, the studies analyzed within the scope of this research; It consists of 14 master's theses, 9 PhD dissertations and 7 research articles. 19 of these studies were conducted on secondary school, 7 on higher education and 4 on high school students.

RESULTS

In this section, after examining the publication bias, findings on whether IBL has a significant impact on academic achievement based on various educational levels and the types of publication of the researches.

Publication Bias

One of the most effective methods of testing publication bias in meta-analysis studies can be investigated by a funnel plot. While effect sizes are shown on the horizontal axis in the funnel chart, sample sizes are shown on the vertical axis. The studies are expected to show a symmetrical distribution within the funnel lines. In this direction, the funnel plot of the studies included in this study was given in Figure 2.

When the graph in Figure 2 was examined, it can be seen that all studies except for six of them were included in the funnel plot lines, the sample sizes of the studies were close to each other, and the studies were symmetrically distributed around the middle line representing the general effect. Based on these results, it was concluded that publication bias was too low to affect the reliability of the study. In this sense, Duval and Tweedie's (2000) trim and fill method is a test that shows how many possible missing studies are needed to correct publication bias, and the filled circles show the fictitious studies that should be included to eliminate publication. The values obtained as a result of the test were given in Table 2. According to these results, if 9 possible missing studies were added to correct publication bias, the effect size would increase from 1.181 to 1.433.

In addition to Duval and Tweedie's trim and fill test, another method of testing publication bias in a study involving meta-analysis is Egger's test. If Egger's *p* value obtained as a result of the test was above 0.05, it means that publication bias is not statistically significant. Accordingly, the results of Egger's test were given in Table 3. Egger's significance values ($p > 0.05$) according to the test results show that there is no publication bias in this study. Egger's test result is

Figure 1. Flow chart on the inclusion process of researches

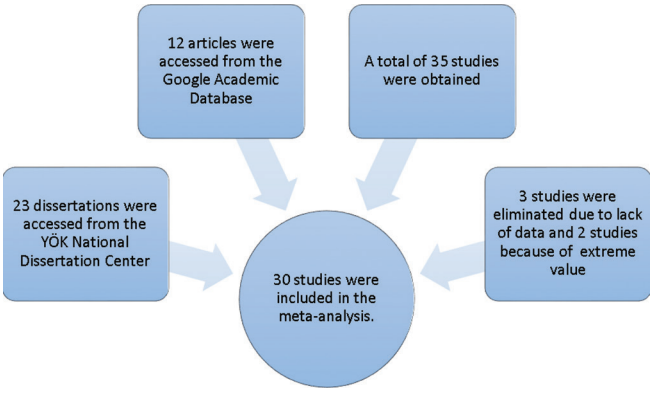

Figure 2. Funnel plot showing publication bias

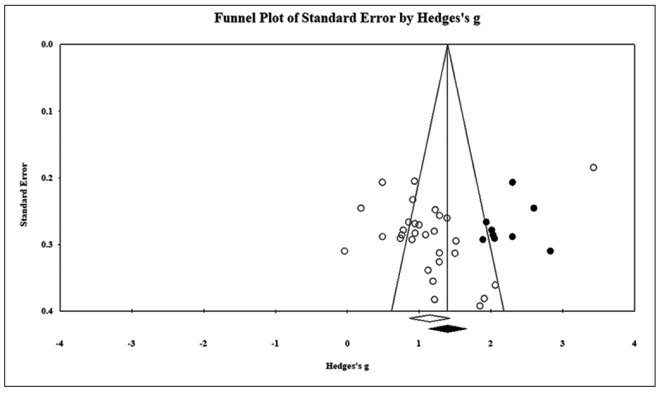

Table 1. Descriptive information about studies included in the study

Identity of the research		Level of Education	Type of Publication	Experiment Group	Control Group	Effect Size
1	Şimşek (2013)	Secondary school	PhD dissertation	20	20	0.00
2	Çakar (2013)	Secondary school	PhD dissertation	30	29	1.23
3	Türker Altan (2015)	Secondary school	Master's thesis	38	38	1.41
4	Karakoç (2016)	Secondary school	PhD dissertation	19	20	1.29
5	Kurtulmuş (2017)	Secondary school	Master's thesis	25	26	0.67
6	Varlı (2018)	Secondary school	Master's thesis	15	16	1.32
7	Özkanbaş (2018)	Secondary school	Master's thesis	27	27	1.00
8	Göreci Keskin (2019)	High school	Master's thesis	20	19	2.01
9	Kaçar (2020)	Secondary school	PhD dissertation	40	40	1.13
10	Tatar (2006)	Secondary school	PhD dissertation	52	52	1.00
11	Taşkoyan (2008)	Secondary school	Master's thesis	18	18	1.98
12	Eyvazoğlu (2008)	Higher education	Master's thesis	27	28	1.21
13	Calışkan (2008)	Secondary school	PhD dissertation	30	30	0.88
14	Altunsoy (2008)	High school	Master's thesis	18	18	1.33
15	Bağcaz (2009)	Secondary school	Master's thesis	30	30	1.33
16	Kula (2009)	Secondary school	Master's thesis	30	30	0.88
17	Parim (2009)	Secondary school	PhD dissertation	24	25	0.78
18	Şensoy (2009)	Higher education	PhD dissertation	45	50	0.31
19	Can Şen (2010)	High school	PhD dissertation	189	109	3.44
20	Sakar (2010)	High school	Master's thesis	27	27	1.00
21	Akpullukçu (2011)	Secondary school	Master's thesis	36	36	1.41
22	Çelik (2012)	Secondary school	Master's thesis	22	22	1.33
23	Alkan Dilbaz (2013)	Secondary school	Master's thesis	24	24	0.57
24	Kaya and Yılmaz (2016)	Secondary school	Article	33	32	0.00
25	Bozkurt (2012)	Higher education	Article	25	25	2.00
26	Karakuyu et al. (2013)	Higher education	Article	25	26	1.53
27	Çelik and Çavaş (2012)	Secondary school	Article	24	24	1.33
28	Öz and Şahin (2015)	Secondary school	Article	29	29	1.96
29	Bozkurt et al. (2013)	Secondary school	Article	23	23	2.24
30	Yetişir (2016)	Higher education	Article	35	37	2.00

Table 2. Duval and tweedie's trim and fill test (random effects)

	Omitted Studies (Right)	ES]	Confidence Interval		*Q*
			Lower Limit	Upper Limit	
Observed Values		1.181	0.869	1.426	226.364
Corrected Values	9	1.433	1.138	1.657	340.364

ES (Effect Size)

supported by Begg's test result (tau b = 0.237, p = 0.066), and publication bias was not found to be critically significant for the present study.

Table 3. Egger's test results

Intercept	-2.669
% 95 lower limit	-8.405
% 95 upper limit	3.065
t value	0.954
df	28
p value (tag-1)	0.174
p value (tag-2)	0.348

Effect of IBL on Academic Achievement

In this section, the impact of IBL on academic achievement has been investigated given the changes from pre-test to post-test scores of the students. Table 4 contains the effect sizes calculated according to the fixed effects model

and random effects model as well as the heterogeneity test results.

As seen in Table 4, the *Q* value is calculated as 226.36 ($p < .01$). The value of *Q* is greater than the value corresponding to 29 degrees of freedom (*df*) in the x^2 table. Based on this result, it can be concluded that the works included in the study are not similar, in other words, they are heterogeneous. Another way to test heterogeneity is the I^2 percent value. The I^2 value of this study (i.e., 87.19%) confirms that the works included in the study were heterogeneous. Since the research has a heterogeneous structure, the effect size value obtained in the random effects model was taken into consideration, which was calculated as 1.147. According to Cohen's (1988) classification, it has been observed that IBL has a large level effect on students' academic achievement. The 52.2% distribution of the actual effect sizes ($\tau^2 = 0.522$) was explained by this study.

In this direction, the forest plot created according to the random effects model was given in Figure 3. When the forest plot was examined, it is seen that all effect sizes of the studies are positive. As a result of the comparison of the experimental groups with the control groups included in this study, the finding showed that inquiry-based learning (IBL) positively affects academic achievement.

Comparison of Groups According to School Level and Article Type

In Table 5 below, the comparisons of the effect of IBL on academic achievement by education level and type of publication were given.

Table 4. Heterogeneity test results

Model	*N*	ES	*z*	*SE*	Lower Limit	Upper Limit	*df*	*Q*	*p*	I^2
Fixed Effects	30	1.181	23.42	0.050	1.08	1.28	29	226.36	.00	87.19
Random Effects	30	1.147	8.06	0.142	0.87	1.43				

Figure 3. Forest plot created according to random effects model

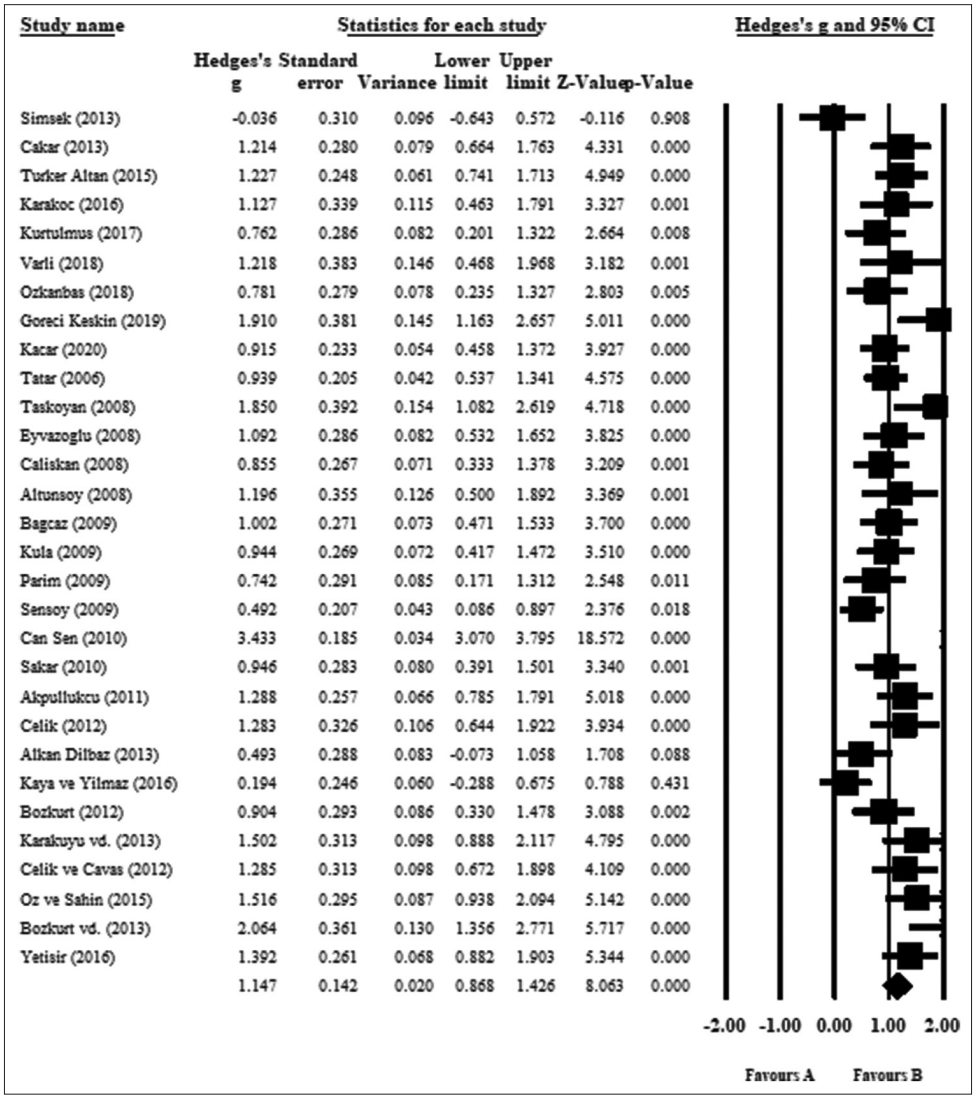

Table 5. Subgroup analysis according to random effects model

Variable		*N*	ES	SE	Lower Limit	Upper Limit	*df*	*Q*	*p*
Level of Education	Secondary School	21	1.016	0.136	0.750	1.282	2	7.493	0.024
	High School	4	1.944	0.313	1.330	2.558			
	Higher Education	5	1.063	0.274	0.526	1.600			
Type of Publication	Master's Thesis	14	1.131	0.217	0.706	1.555	2	0.166	0.921
	PhD Dissertation	9	1.092	0.264	0.574	1.611			
	Article	7	1.251	0.305	0.654	1.859			

In line with the results presented in Table 5, Analog ANOVA analysis was conducted to test whether the effect sizes differ by the school levels and the types of publication. As a result of the analysis, it was determined that the heterogeneity value ($Q = 7.493$, $p < 0.05$) according to the school levels was greater than the chi-square critical value. This result showed significant differences between the groups. While average effect sizes of secondary school and higher education levels were close to each other, the average effect size of high school level was higher than secondary school and higher education levels. It was determined that the heterogeneity value ($Q = 0.166$, $p > 0.05$) according to the type of publication was lower than the chi-square critical value. This result displayed no significant differences between the groups. In short, the average effect sizes of the effect of IBL on academic achievement did not vary based on the types of publication.

DISCUSSION

This meta-analysis study, which aims to determine the effect of IBL on the academic achievement of students, was limited to 30 studies within certain criteria. In this study, the effect size (ES = 1.147) obtained in the meta-analysis study was high and positive. Sarı and Şaşmaz Ören (2020) determined that the effect size value (ES = 0.70) has a medium effect size and that there is a statistically significant difference given the meta-analysis study conducted in order to determine the effect of IBL on the academic achievement of students. The effect size (ES = 1.029) obtained in the meta-analysis study conducted by Aktamış et al. (2016) with the same purpose was high and positive. Therefore, it can be concluded that the effect of IBL on the academic success of students is more positively effective than other teaching methods (teaching methods applied in control groups). This result coincides with studies in the literature showing that IBL has a great and positive impact on students' academic success. In this case, it has shown that the result of this study is consistent with the relevant literature and that IBL significantly increases the students' academic achievement.

According to the results of this study, the effect of IBL on academic achievement is higher at high school level than secondary school and higher education levels. In the meta-analysis study conducted by Sarı and Şaşmaz Ören (2020) on the impact of IBL on academic achievement, the effect size at the secondary school level is higher. However, when the study of Sarı and Şaşmaz Ören (2020) was examined in detail, it was found that there was no sample at the high school level in the study of the researchers.

Furthermore, no significant differences were observed in this present study based on the type of publication (dissertation-article). This result coincides with the work of Sarı and Şaşmaz Ören (2020) because they also did not obtain significant differences based on the type of publication. However, in both studies conducted at the article level, the effect of IBL on the academic success of students was significant.

CONCLUSION

In this meta-analysis study conducted to determine the effect of IBL on academic achievement, inquiry-based learning has a high positive effect on the academic achievement of students. There is a significant difference observed in effect sizes because of the school levels. Moreover, while the effect sizes of secondary school and higher education levels are close to each other; the effect size of high school level is significantly higher than secondary school and higher education levels. Based on this result, it can be interpreted that inquiry-based learning gives more effective results at the high school education level; in other words, it is more effective on academic achievement than other education levels. Nevertheless, no significant differences were found due to the type of publication as a result of the Analogue ANOVA test conducted to examine whether the effect sizes of the IBL on the academic achievements vary by the type of publication.

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