Journal of Pedagogical Research
Volume 6, Issue 4, 2022
https://doi.org/10.33902/JPR.202217481

Research Article

Does inquiry-based learning model improve learning outcomes? A second-order meta-analysis

Bilge Öztürk[1], Metin Kaya[2] and Mustafa Demir[3]

[1]*Bayburt University, Faculty of Education, Turkey (ORCID: 0000-0003-1788-9208)*
[2]*Bayburt University, Faculty of Education, Turkey (ORCID: 0000-0002-8287-4929)*
[3]*Bayburt University, Faculty of Education, Turkey (ORCID: 0000-0002-0159-8986)*

This research study aims to utilize a second-order meta-analysis procedure to synthesize the effects of inquiry-based learning model (IBLM) on learning outcomes. An extensive systematic review process resulted in the inclusion of 10 meta-analyses conducted between 2015 and 2022 with minimal overlap between primary studies. The results revealed that IBLM has a medium-level positive effect ($d = 0.62$) on learning outcomes. The analyses showed that mobile inquiry-based model, learning cycle model and conceptual change text model have high-level positive effect on learning outcomes. Moderator analyses revealed that the effect sizes were not significantly moderated by grade level, content area, location, quality, primary research report type, and publication bias. Limitations, educational implications, and directions for future research are provided.

Keywords: Inquiry-based learning model; Learning outcomes; Meta-analysis; Second-order

Article History: Submitted 12 June 2022; Revised 22 August 2022; Published online 22 September 2022

1. Introduction

Throughout history, humans have always been curious, sensitive, and eager to learn about the nature of existence; this process begins at birth and continues to the end of their lives. Curiosity and discovery, which are inherent in human beings, lead us to question everything, aid in decision-making, and develop high-level thinking skills. It is essential that individuals develop their creativity, along with their high-level thinking skills, such as critical and analytical thinking, decision-making, evaluation, accurate analysis, and synthesis. To achieve these, they must actively participate in learning environments by putting their dreams into practice, analyzing, discovering, researching, and asking questions. Individuals who actively participate in learning and make research are likely to sustain knowledge and support learning processes. The act of learning relies on the sense of curiosity, asking questions, and finding correct answers that are understandable and reliable. It is important to make curiosity a priority and to encourage questioning eagerness. Additionally, it is important to guide students in asking sensible questions, to establish environments that facilitate the question-creation process, and to facilitate a healthy inquiry process. Using an inquiry-based approach in the teaching-learning process becomes imperative at

Address of Corresponding Author

Mustafa Demir, PhD, Bayburt University, Faculty of Education, 69000, Bayburt, Turkey.

mustafademir82@hotmail.com

How to cite: Öztürk, B., Kaya, M., & Demir, M. (2022). Does inquiry-based learning model improve learning outcomes? A second-order meta-analysis. *Journal of Pedagogical Research, 6*(4), 201-216. https://doi.org/10.33902/JPR.202217481

this point, as this approach ensures that students have important learning skills and supports their learning outcomes.

Inquiry-based learning (Bozkurt et al., 2013), which is rooted in the philosophical movement of pragmatism -the basis of most learning approaches- also emphasizes the idea of being active and learning through research (Ormancı & Balım, 2019; Tatar, 2006). The National Research Council [NRC], 2000], considers inquiry-based learning as one of the most important learning approaches around the globe. As a result, it is included in many international research and development projects and education programs. A learning approach based on inquiry emphasizes using the methods of scientists to construct knowledge (Green et al., 2004). In this approach, learners create their own hypotheses and test them carefully (Keselman, 2003). In this learning model, students are encouraged to question, criticize, think creatively and reflectively, solve problems, and develop scientific process skills. Moreover, it enables students to gain skills and knowledge that will be needed in their lives as well as improve those skills and knowledge over time (Duban, 2008; Saka & İnaltekin, 2021; Schroeder et al., 2007; Şaşmaz-Ören & Sarı, 2019). Through practices under the guidance of teachers, students internalize knowledge and skills that are acquired through inquiry-based learning (Tezel, 2018). Therefore, students gain scientific knowledge through personal experience and have permanent knowledge. As an active learning approach, inquiry-based learning involves students engaging in the activities of research and analysis throughout their learning experience (Levy et al., 2009). The learning model, which is a process-based approach, is characterized by five significant characteristics that can be implemented across all levels of learning. Below are the five essential features explained by NRC (2000):

i. Learners are engaged by questions oriented in science

ii. Learners address questions through evidence and evaluation of explanations

iii. Learners indicate new explanations that utilize evidence that they create to answer questions

iv. Learners consider alternative explanations and evaluate peer learners rationalizations

v. Learners justify and communicate their selected explanation (as cited in Thoron et al., 2011, p. 96).

According to these characteristics of the learning process, the primary purpose of the inquiry-based learning approach is not to provide the correct and whole information; rather, it is to develop their research and questioning skills so that they can become active participants in the learning process and, as a consequence, acquire knowledge through their own experiences.

Based on the level of participation in the education process, inquiry-based learning suggests three methods: constructed inquiry, guided inquiry, and open-ended inquiry (NRC, 2000; Sadeh & Zion, 2012). In constructed inquiry-based learning processes, teachers are mostly active and students are solely responsible for establishing relationships, asking questions, and discovering the topic (Bozkurt et al., 2013). Although guided inquiry is partially similar to constructed inquiry, it requires deeper questioning from students since it prioritizes learners' experiences (Zion & Mendelovici, 2012). Rather than placing the teacher at the center of inquiry-based learning, open-ended inquiry requires students to work like scientists. In the open-ended inquiry-based method, students first define the problem, then construct a hypothesis, determine variables, develop different methods for solving the problem, choose problem-solving processes, and make discoveries based on the results they obtain (Çepni & Ayvacı, 2016). These three approaches to inquiry-based learning enable students to share their views during the questioning process, support or challenge one another's ideas, and freely express themselves (Duban, 2014).

Literature analysis shows that different researchers have described inquiry-based learning in different stages. For example, Lim (2004) suggests that inquiry-based learning involves asking, planning, discovering, creating, and reflecting. Bell et al. (2010) suggest a comprehensive inquiry-based process based on different research results and state that there are nine steps to this process: Developing a hypothesis, planning, researching, analysing, interpreting data, creating and searching for a model, finalizing and evaluating, communicating, and calculating. The five-stage inquiry cycle proposed by Bruce and Casey (2012) involves asking, researching, creating, discussing, and reflecting. The inquiry frame presented by Pedaste et al. (2015) consists of orientation, conceptualization, investigation, conclusion, and discussion. Although different inquiry processes are identified by the researchers, it is vital to keep in mind that the process starts by asking a question and ends with an evaluation and conclusion. Although there are differences throughout the process, it is determined that IBLM is an effective model in terms of learning outcomes according the reearch results (Nasution, 2018; Ödün-Başkıran & Korkmaz, 2020; Varlı & Uluçınar-Sağır, 2019, 2020; Zweers et al., 2019) as well as meta-analysis studies (Aktamış et al., 2016; Heindl, 2019; Lazonder & Harmsen, 2016; Sarı & Şaşmaz-Ören, 2020; Şaşmaz-Ören & Sarı, 2019; Yang et al., 2020). In spite of the fact that meta-analysis studies make important contributions to the related literature, comprehensive meta-analysis studies focusing on the impact of inquiry-based learning on learning outcomes are needed. It is evident from the literature review that there is no comprehensive study of the effects of inquiry-based learning on learning outcomes. To fill this gap, this study will analyze a number of meta-analyses and synthesize their findings. This study aims to synthesize the results of meta-analyses of the impact of inquiry-based learning on learning outcomes.

1.1. Effect of Inquiry-based Learning and Potential Moderator Variables

Analysis of the research shows that there are moderator variables that can influence the impact of inquiry-based learning on learning outcomes. Types of IBLM are the first potential moderator variable to be considered. Lazonder and Harmsen (2016) found that impact sizes varied according to IBLM types, whereas Yang et al. (2020) found no statistical difference. Cakir (2017) and Şaşmaz-Ören, and Sarı (2019) found that different types of IBLM affected learning outcomes in different ways. Additionallu, the efficiency of IBLM may change in terms of content areas. Zheng et al. (2018) and Çakır and Güven (2019) observed that content area is a variable in terms of IBLM. According to Armagan et al. (2017), another potential variable is defined as grade level. According to Kaçar et al. (2021), it depends on the educational level, with higher education being more effective than lower grades. Higgins and Green (2011) found that location plays an important role in publication bias. In other words, the location of where the research is conducted can affect impact size. Furthermore, the quality of meta-analysis research depends on the reliability of the impact size calculation and the research type (Kung et al., 2010). Consequently, IBLM type, content area, educational level, location, meta-analysis quality, primary research report type, and publication bias were included as moderator variables.

1.2. The Aim

This research study aims to utilize a second-order meta-analysis procedure to examine the effects of inquiry-based learning model (IBLM) on learning outcomes. Within the scope of this study, the answers to the following questions are examined:

RQ 1) How does the effectiveness inquiry-based learning approach on learning outcomes?

RQ 2) What moderator variables (IBLM type, content area, educational level, location, meta-analysis quality, primary research report type, publication bias) influence the effectiveness of inquiry-based learning approach on students' learning outcomes?

2. Method

A second-order meta-analysis method is adopted into this study. Second-order meta-analyses are a method used for synthesizing the findings of first-order meta-analysis research (Schmidt & Oh, 2013). A second order meta-analysis combines previous meta-analyses findings (Oh, 2020). This method is preferred in this study to determine the impact level of IBLM on learning outcomes.

2.1. Data Collection

To locate relevant studies, an intensive literature review was conducted and major databases (Scopus, Web of Science, ERIC, Academic Search Ultimate, TR Index, and Google Academic) were searched using the keywords: Inquiry, discovery, learning cycle, conceptual change, meta-analysis, and meta-analytic. Both English and Turkish research studies were included in the analysis. Pre-inclusion criteria were determined to meet the purposes of this research.

2.2. Inclusion Criteria

The following inclusion criteria were considered:

i. Meta-analysis research should be published between the years 2015 and 2022 in either English or Turkish languages.

ii. Meta-analysis research should focus on the relationships between IBLM and learning outcomes.

iii. Meta-analysis research should involve statistical data sufficient for calculating effect size (e.g. Cohen's d, Hedge's g, lower-limit (LL), upper-limit (UL), and standard error (SE), depending on this impact size and variance value).

iv. There should be more than 25% overlapping between meta-analysis researches.

2.3. Overlapping Issue

Correspondence is one of the problems encountered in the second order of Meta-analysis. The problem stems from the fact that different meta-analyses contain the same basic research. A meta-analysis whose overlapping ratio is greater than 25% is preferred for this study (Cooper & Koenka, 2012). This research includes the most recent and comprehensive meta-analysis research. Other meta-analysis research which does not meet these criteria were excluded. In Appendix 2, we present the meta-analysis researches that we excluded because of overlapping issues.

The abstracts and methods of 22 studies that meet the criteria for inclusion are analyzed, and the overlaps are determined. A total of 12 research studies with an overlapped problem and insufficient statistical data are excluded. In total, 10 researches were included in this study. The data flow chart is presented in Figure 1. In Appendix 1, we describe the features of meta-analysis research that make the dataset for this study.

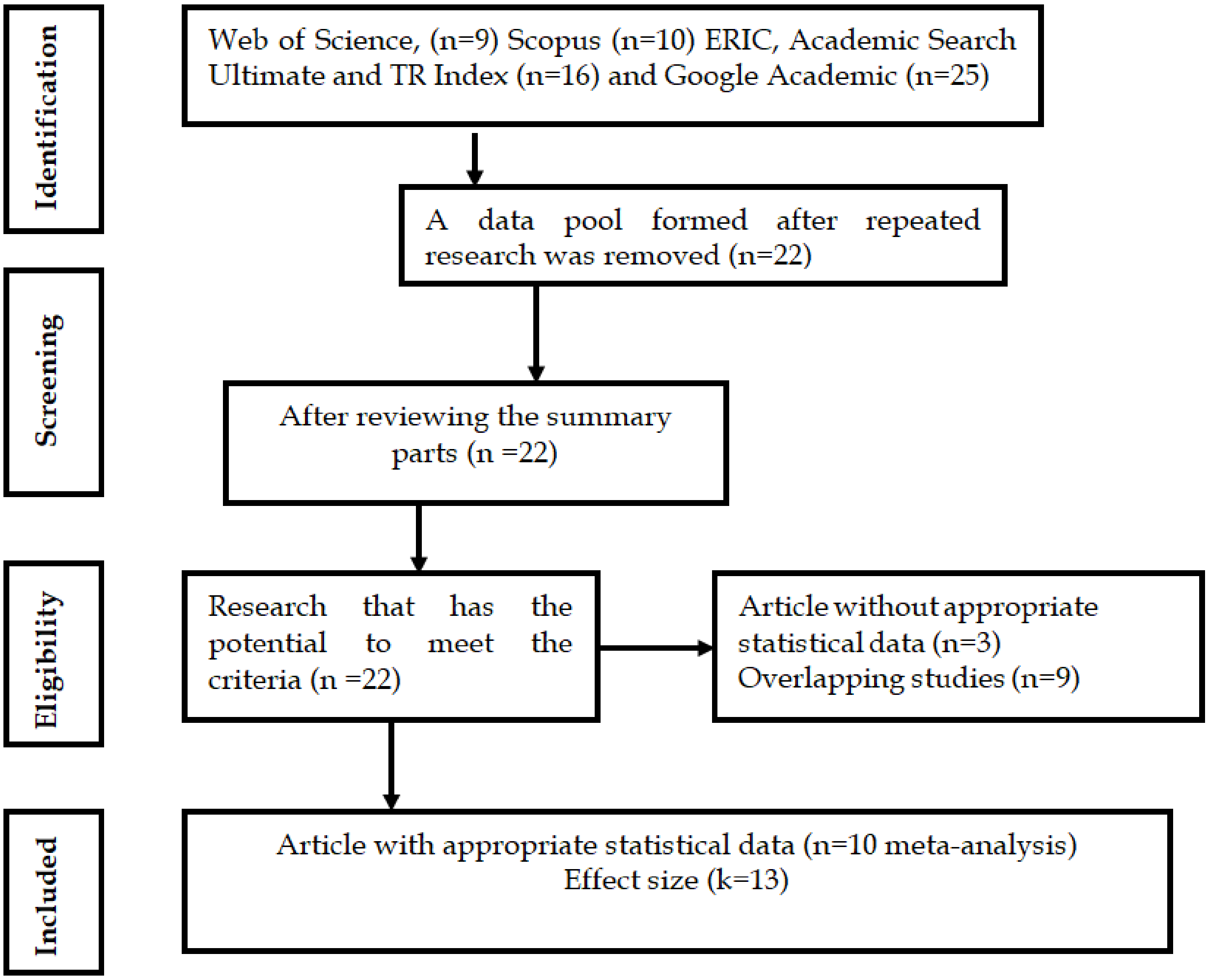
2.4. Coding

A total of ten meta-analyses that meet the criteria of this research have been coded. Coding is carried out by the first/second researcher. Coding forms are created that reflect the characteristics of meta-analysis research. Table 1 provides a summary of coding information.

Table 1
Coding Process

Group	*Code*
Study	researcher/s (publication year)
Inquiry-based learning	inquiry based model (general), mobil inquiry based model, learning cycle model and conceptual change text model
Learning outcomes	academic achievement, thinking skill and affective features
Content area	science, math and mixed (science, math and other)
Grade level	K12, and mixed (K12 + higher)
Primary research report type	article and (un)published dissertation and mixed
Location	mixed, Turkey and China
Meta analysis quality	insufficient, low, medium and high
Publication bias	low, trivial, no and unknown

Figure 1
Flow chart of the literature search



2.5. Evaluation of the Quality

Meta-analysis research is evaluated using the revised Assessment of Multiple Systematic Reviews (R-AMSTAR) scale (Kung et.al., 2010). The scale consists of 11 sections. The 8th section contains articles 8A and 8B, which are used for clinical practice. Therefore, they are not included in the evaluation. Scale scores are evaluated according to the ranges suggested by Young (2017).

2.6. Statistical Independence

Meta-analysis research that presented impact size on more than one learning type is coded as Meta-analysis. For instance, meta-analysis research analyzes the impact of IBLM on academic performance and cognitive features, related impact sizes are considered independent.

2.7. Statistical Model

Borenstein et al. (2011) suggest using the random effect model if the sampling and characteristics of the combined research are different. Samplings and features of meta-analysis research used in this study are different. Therefore, random effect models are used in statistical analyses.

2.8. Calculation of Impact Size

The data set of this study consists of 7 studies containing Cohen's d value and 6 studies containing Hedge's-g value. Cohen's d and Hegde's g impact size calculation methods yield similar results (Marfo & Okyere, 2019; Turner& Bernard, 2006). In smaller samples, Hedge's g value is corrected to Cohen's d value (Goulet-Pelletier & Cousineau, 2018; Marfo & Okyere, 2019). The sampling sizes included in this study are considered large enough for meta-analysis. A similar approach is used in second-order meta-analysis research (Hew et al., 2021; Tamim et. al, 2011; Young, 2017). The above-mentioned explanations are taken into account when combining Hedge's g and Cohen's d values. In order to determine the effect size, Cohen's d value is considered.

2.9. Analysis of Publication Bias

Publication bias is closely related to the reliability of calculated impact size (Borenstein et al. 2011). The publication bias can be tested using a variety of statistical techniques. Funnel plot graphic analysis, Egger's regression test, Begg and Mazumdar rank correlation test, and Duval and Tweedie, trim and fill analysis (DTTF) techniques are used (Jin et al. 2015) to test the publication bias of the dataset.

2.10. Moderator and Heterogeneity Analysis

In this meta-analysis study, it was examined whether IBLM type, content area, educational level, location, meta-analysis quality, primary research report type, and publication bias were moderator variables that affect learning outcomes. The Q between tests was used to determine whether the mean impact size varied based on the moderators. In addition, Q statistical technique was used to calculate the total heterogeneity of the dataset.The I^2 value was used to determine the degree of heterogeneity in the dataset (Higgins et al., 2003).

3. Findings

A description of the dataset, the mean impact size, publication bias, and the moderator and heterogeneity analyses are presented in this section.

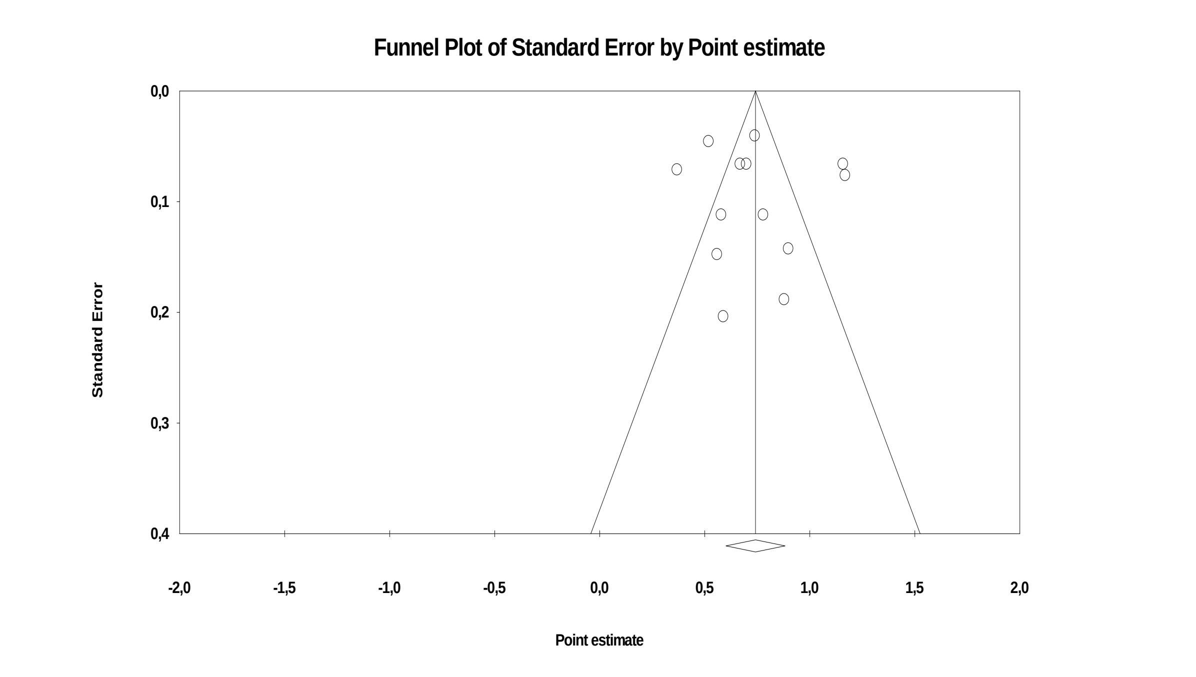
3.1. Descriptive Statistics and Mean Impact Size

The dataset of IBLM and learning outcomes includes n=10 meta-analyses. The research group involves a total of 462 participants. The dataset contained 13 impact sizes. In the dataset, the impact sizes range from ES=.37 to ES=1.17. The mean impact size is calculated as ES=.74 LL=.60 UL=.88. Therefore, IBLM has a medium impact on learning outcomes. The total heterogeneity amount of the dataset is found to be Q (12) =128.17. The heterogeneity level of the dataset is high (I^2 = 90.64).

3.2. Publication Bias

Analyzing the funnel plot graphic of the dataset, it is observed that impact sizes are distributed symmetrically according to standard deviation. Figure 2 shows a funnel plot of the dataset. Egger's regression test (t=.37; p=.72) and Begg and Mazumdar rank correlation test (tau=.04; p=.85) indicate that there is no publication bias. Furthermore, no research has been conducted on which DTTF test results should be added. As a result of these publication bias analyses, the dataset does not exhibit any publication bias.

Figure 2
Funnel plot graphic



3.2. Moderator and Heterogeneity Analyses

Moderator and heterogeneity analyses are presented in Table 2.

Table 2
Moderator and heterogeneity analyses of the dataset

Group	*k*	*ES*	*LL*	*UL*	*Q(b)*	*df (Q)*	*p*
Model							
Inquiry based (general)	7	0.62	0.49	0.75			
Mobil inquiry based	3	0.81	0.54	1.08			
Learning cycle	2	0.90	0.65	1.16			
Conceptual change text	1	1.17	0.82	1.52	10.83	3	0.01
Outcomes							
Academic achievement	8	0.80	0.61	0.98			
Thinking skill	2	0.72	0.35	1.09			
Affective	3	0.58	0.24	0.91	1.30	2	0.52
Grade level							
K-12	4	0.60	0.35	0.85			
Mixed	9	0.81	0.63	0.98	1.70	1	0.19
Content area							
Mixed	10	0.74	0.58	0.89			
Math	1	0.52	0.07	0.97			
Science	2	0.90	0.55	1.25	1.72	2	0.42
Location							
Mixed	6	0.70	0.48	0.92			
Turkey	6	0.82	0.61	1.02			
China	1	0.52	0.04	1.00	1.53	2	0.47
Quality							
Medium	9	0.75	0.59	0.92	0.08		
High	4	0.71	0.43	0.99		1	0.78

Table 2 continued

Group	k	ES	LL	UL	Q(b)	df (Q)	p
Primary research report type							
Mixed	8	0.67	0.51	0.83			
Article	4	0.78	0.53	1.03			
(Un)published dissertation	1	1.16	0.72	1.60	4.35	2	0.11
Publication bias							
No	5	0.72	0.49	0.95			
Trivial	3	0.80	0.46	1.14			
Low	3	0.84	0.56	1.13			
Unknown	2	0.56	0.20	0.93	1.55	3	0.67

It was revealed that mean impact size statistically varies according to inquiry-based learning models (types) (Q (3)=10.83 p=.01). The impact of mobile inquiry-based (ES=.81), learning cycle model (ES=.90), and conceptual change text model (ES=1.17) on learning outcomes is high while the impact of the inquiry-based model (ES=.62) on learning outcome is medium-level. Besides, impact sizes of the type of outcomes, grade level, Content area, location, quality, primary research report type, and the publication bias do not statistically vary according to moderator variables.

4. Discussion, Conclusion and Suggestions

Based on the results of this study, inquiry-based learning has a medium-level effect on learning outcomes. In inquiry-based learning, students follow similar methods and practices to scientists (Keselman, 2003; Pedaste et al., 2015). Thus, this method can be defined as the process of creating hypotheses, testing them through observations or experiments, and discovering new causal relationships (Green et al., 2004; Pedaste et al., 2012). In this manner, inquiry-based learning aims at teaching students "the process of learning" (Shih et al., 2010); thus, important learning outcomes are expected from students as a result. In inquiry-based learning, students are encouraged to actively participate and discover new information (de Jong & van Joolingen, 1998). In addition to improving academic success, students develop high-level thinking, scientific process skills, and cognitive skills. Through inquiry-based learning, students relate concepts of a specific issue with real-life problems, and they are then able to propose solutions to these problems (Şaşmaz-Ören et al., 2010). As students are involved in the process from a variety of angles, inquiry-based learning can contribute to their academic success. The inquiry-based learning approach promotes the use of reasoning and questioning on different issues, enabling students to make scientific research and reach scientific solutions. This method helps students acquire more sustainable and meaningful knowledge and become more successful academically.

While inquiry-based learning gives students the opportunity to learn through experience, it also improves different abilities. Additionally, they learn new skills that will help them throughout their lives (Branch & Solowan, 2003). A variety of literature studies indicate that students are supported and developed in scientific process skills, creativity, reflection, analytical and critical thinking (Agrusti, 2013; Friedel et al., 2008; Oliver, 2008; Saka & İnaltekin, 2021; Şaşmaz-Ören & Sarı, 2019). Because inquiry-based learning involves a dynamic process, students are highly active mentally. Throughout the learning process, this activity supports students' scientific process skills and thinking skills. The inquiry-based learning method improves students' cognitive skills by promoting academic success, scientific process skills, and thinking skills. An increase in academic success directly and positively impacts self-esteem and motivation in class. A second reason why inquiry-based learning methods should be used is that students are encouraged to actively engage throughout the learning process; this means that they will develop a sense of respect for one another, start to value one another, and will increase their communication skills. It not only increases students' self-esteem, but also makes them more positive about their classes. Inquiry-based learning plays a crucial role in ensuring students develop cognitive, affective, and permanent skills. Furthermore, inquiry-based learning provides individuals with the opportunity to understand scientific knowledge and become scientifically literate. For inquiry-based learning to be implemented in classrooms of all education levels, appropriate organizational changes can be made; this will allow students to play the role of researchers and learn in a classroom environment that supports their learning.

Inquiry-based learning is an educational approach that requires professionalism. Thus, pre-service and in-service training can be provided at the local level to enable teachers to use the method effectively. Due to the active learning approach, organized education programs should prioritize implementations and activities so that teachers and teacher candidates can adopt it more easily. A variety of materials can be developed to assist teachers in understanding and implementing inquiry-based learning methods. Using these materials can increase students' enthusiasm for inquiry-based learning and serve as guides for teachers to follow the learning process at school. They can include multiple, effective activities that encourage students to engage in inquiry-based learning.

Study results show that inquiry-based learning method types have statistically different mean impact sizes. When compared to a general inquiry-based learning method, conceptual change approach, learning cycle, and mobile inquiry-based learning methods have higher impact sizes on learning outcomes. It is important to note that conceptual change is the type of inquiry-based learning that has the greatest impact. Individuals develop and store concepts in their minds based on their interactions with the environment starting from birth throughout their lives; this significant process occurs based on their interactions with the environment. The teaching and learning of different concepts is important at all levels and fields of education as concepts are the main sources of information to be acquired. Concept education emphasizes learning concepts correctly at the beginning and constructing them correctly. Therefore, many methods, models, approaches, techniques, and graphic materials are used in education to ensure an efficient concept teaching process. In this regard, conceptual change is one of the approaches. This approach prioritizes separating students from non-scientific information, in other words, misconceptions.

It's an alternative approach aimed at enabling students to get scientifically correct information. This encourages students to acquire correct, reliable scientific knowledge (Çelikkaya & Şarlayan, 2019; Wang & Andre, 1991). According to Yılmaz (2010), the conceptual change approach is the most enlightening method in the process of constructing concepts. Considering this acceptance, it can be concluded that conceptual change approaches are frequently used when teaching concepts; their high impact size may explain this. The study also found a high impact size for the learning cycle model and mobile inquiry-based learning methods. These high impact sizes are expected due to their recent use as active learning approaches and the high impact they have on learning. The learning cycle is a flexible model for reflection and constructive learning in education (Saraç, 2018). This model is based on the process of discussing knowledge students acquire through conceptual development in classes (Özmen, 2016). It is regarded as a way to construct an inquiry-based learning method (Marek, 2008). The model of the learning cycle gives students the chance to construct concepts, benefit from personal experience and find solutions to problematic situations (Kanlı, 2009; Şaşmaz Ören & Tezcan, 2009); the steps include analyzing concepts, making discoveries, collecting data, recognizing and constructing data, and applying data. Based on these steps, it is evident that the model plays a significant role in the effective implementation of teaching concepts. Many research studies have shown that the learning cycle model supports the scientific process, high-level cognitive and affective skills, and academic achievement (Ateş & Polat, 2005; Doğru-Atay &Tekkaya, 2008; Durukan, 2018; Kitjinda-Opas et al., 2009; Wise & Bluhm, 2008). In this study, the impact of inquiry-based learning on learning outcomes was medium-level, as mentioned previously. This finding supports the effects of the learning cycle, which is a type of inquiry-based learning method.

Mobile inquiry-based learning was found to be very effective in students' learning processes. As is well known, mobile devices are used everywhere, in every aspect of life. These devices are used very often by young people due to their features such as internet access, portability, and easy communication. As a result of these advantages, the devices are now being used in the field of education (Bai, 2019; Gierdowski, 2019; Özdener & Demirci, 2019). Students have access to an unaccountable amount of resources when using mobile devices in real-life contexts (Huang et al., 2017). According to Hwang et al. (2018), mobile devices facilitate peer communication and foster high-level thinking abilities such as critical thinking and creativity. In addition, mobile devices support high-cognitive processes, allow students to complete activities outside of school, conduct more research, and learn from a variety of resources (Sha et al., 2012; Sullivan et al., 2019). Using the inquiry-based learning method, mobile devices can make valuable contributions to learning. Mobile inquiry-based learning method, which supports students in terms of academic success, motivation, high-level cognitive thinking, and learning (Hwang et al., 2018; Nikou &Economides, 2018; Sha et al., 2012), may have a greater impact on learning outcomes than inquiry-based learning methods. In this sense, the revealed result shouldn't come as a surprise.

It is evident from the study that mobile devices and other educational technologies can increase the productivity of inquiry-based learning methods. Analyzing the issue from a more specific perspective, school and classroom environments can be enhanced to allow use of mobile devices and other education technologies according to the principles of inquiry-based learning. Additionally, teachers and school managers can be encouraged to use inquiry-based learning methods.

In the context of general evaluation, when one considers the various dimensions (high-level thinking, scientific process skills, affective skills, problem solving, reasoning, questioning, etc.) outlined above, as well as the impact of inquiry-based learning on learning outcomes, it becomes apparent why the approach is valuable. In this regard, it is necessary to adopt and support inquiry-based learning, with the prediction that it will significantly facilitate the learning process. As important as this issue is for teachers, prospective teachers, and students, it is also very valuable for other stakeholders involved in education and teaching. The education-teaching process is collaborative with all its stakeholders. In order to maximize the contribution of inquiry-based learning, stakeholders should be aware of the features and benefits of the approach. In addition, this study, which provides a framework for the impact of inquiry-based learning types, offers a guide for teachers who are currently involved in the education-teaching process and for prospective educators.

An analysis of the issue from a general perspective suggests that the results of this study are important since they provide a detailed analysis of the inquiry-based learning approach and emphasize its main features. This study reveals in detail how inquiry-based learning contributes to individual development while also reflecting the effects of inquiry-based learning on learning outcomes. Readers can also examine the effects of inquiry-based learning and see the effect sizes of different types of learning through the study results. Consequently, the study contributes to the understanding of the importance of inquiry-based learning and will guide future studies.

Author contributions: All authors have sufficiently contributed to the study, and agreed with the results and conclusions.

Funding: No funding source is reported for this study.

Declaration of interest: No conflict of interest is declared by author.

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

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Appendix 1. Studies included included in the meta-analysis

Study	*ES*	*LL*	*UL*	*k*	*Level*	*Location*	*Report*
Ören & Sarı (2019)	0.67	0.54	0.79	63	Mixed	Turkey	Mixed
Sarı & Ören (2020)	0.70	0.57	0.83	53	Mixed	Turkey	Mixed
Heindl (2019)	0.74	0.66	0.82	13	K-12	Mixed	Article
Xie et al. (2018)	0.52	0.43	0.61	26	K-12	China	Mixed
Aktamış et al. (2016)	0.56	0.27	0.84	10	K-12	Turkey	Mixed
Yang et al. (2020)	0.90	0.62	1.18	41	Mixed	Mixed	Article
	0.88	0.51	1.25		Mixed	Mixed	Article
	0.59	0.19	0.99		Mixed	Mixed	Article
Sarac (2018)	1.16	1.03	1.30	123	Mixed	Turkey	(Un)published dissertation
Cakir (2017)	0.58	0.36	0.81	19	K-12	Turkey	Mixed
Lazonder & Harmsen (2016)	0.78	0.56	1.00	72	Mixed	Mixed	Mixed
	0.37	0.23	0.52		Mixed	Mixed	Mixed
Armagan et al. (2017)	1.17	1.02	1.32	42	Mixed	Turkey	Mixed

Appendix 1 continued

Study	*Model*	*Outcome*	*Content Area*	*Quality*	*Bias*	*Year range*
Ören & Sarı (2019)	IBL	Thinking skill	Mixed	Medium	Low	2000-2016
Sarı & Ören (2020)	IBL	Academic achievement	Mixed	Medium	Low	2005-2017
Heindl (2019)	IBL	Academic achievement	Mixed	Medium	No	2011-2015
Xie et al. (2018)	IBL	Academic achievement	Math	High	No	1986-2015
Aktamış et al. (2016)	IBL	Affective	science	Medium	No	2005-2015
Yang et al. (2020)	(m-IBL)	Academic achievement	Mixed	High	trivial	2001-2017
	(m-IBL)	Academic achievement	Mixed	High	trivial	2001-2017
	(m-IBL)	Affective	Mixed	High	trivial	2001-2017
Sarac (2018)	learning cycle	Academic achievement	Mixed	Medium	Low	2007-2016
Cakir (2017)	learning cycle	Affective	Mixed	Medium	No	2006-2016
Lazonder & Harmsen (2016)	IBL	Thinking skill	Mixed	Medium	unknown	1994-2014
	IBL	Academic achievement	Mixed	Medium	unknown	1994-2014
Armagan et al. (2017)	conceptual change text	Academic achievement	Science	Medium	No	1995-2010

Appendix 2. Studies excluded and selected due to overlap

Excluded	*Included*	*Outcome/model*	*Reason*
Kaçar et al. (2021)	Sarı & Ören (2020)	Achievement	Comprehensive
Aktamış at al. (2016)	Ören & Sarı (2019)	Process Skill	Up-to-date
	Sarı & Ören (2020)	Achievement	Up-to-date
Zheng et al. (2018)	Yang et al (2020)	(m-IBL)	Up-to-date
Yaman & Karaşah (2018)	Saraç (2018)	Achievement	Comprehensive
Batdi et al. (2018)		Achievement	Comprehensive
Balta & Saraç (2016)		Achievement	Up-to-date
Anil & Batdi (2015)		Achievement	Up-to-date
Çakır & Güven (2019)	Çakır (2017) and Saraç (2018)	Attitude and achievement	Comprehensive
Anil & Batdi (2015)	Çakır (2017) and Saraç (2018)	Attitude and achievement	Up-to-date

Note. "**" Studies included included in the meta-analysis

Kaçar, T., Terzi, R., Arıkan, İ., & Kırıkçı, A. C. (2021). The effect of ınquiry-based learning on academic success: A Meta-analysis study. *International Journal of Education and Literacy Studies, 9*(2), 15-23.**

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