Van Yüzüncü Yıl Üniversitesi Eğitim Fakültesi Dergisi, 2024; 21(3), s.893-920.

Van Yüzüncü Yıl University Journal of Education, 2024; 21(3), p. 893-920. DOI: 10.33711/yyuefd.1570041

Effect of the Predict-Observe-Explain (POE) Strategy on Achievement in Science Education: A Meta-Analysis Study

Zeynep KOYUNLU ÜNLÜ[1]

Abstract: Predict-observe-explain (POE) is a strategy that has been used in science education for several decades. It is important to determine how effective this strategy is, especially when used in the constructing scientific concepts. In this study, the effect of the POE strategy on students' science achievement was examined in a meta-analysis. Databases were searched using specific keywords and 35 studies (6 theses and 29 articles) that met the inclusion criteria were found. Hedges' g and the random effects model were used to calculate effect sizes. As a result, the average effect size (g=0.979, 95% CI: 0.771-1.188, p<0.001) was found to be high. The POE strategy was found to increase students' science achievement with a high-level effect. The differences between studies were determined by analog to the ANOVA and meta-regression moderator analyses. While the effect of POE on students' science achievement differed significantly according to the moderators of field of science and level of education, it did not differ significantly according to the moderator of implementation type. The moderators of implementation time and year of publication were similarly not found to be significant predictors of the effect of POE on science achievement. Based on these results, suggestions are made for researchers and practitioners.

Keywords: Predict-observe-explain, science education, academic achievement, meta-analysis

Fen Eğitiminde Tahmin-Gözlem-Açıkla Stratejisinin Akademik Başarıya Etkisi: Bir Meta Analiz Çalışması

Öz: Tahmin gözlem açıklama (TGA) uzun bir süredir fen eğitiminde kullanılan bir stratejidir. Özellikle fen alanındaki kavramların yapılandırıldığı deneylerde kullanılan bu stratejinin ne kadar etkili olduğunun belirlenmesi önemlidir. Bu araştırmada TGA stratejisinin öğrencilerin fen başarısı üzerindeki etkisi meta-analiz yöntemiyle incelenmiştir. Belirlenen anahtar kelimeler ile veri tabanlarında çeşitli taramalar gerçekleştirilmiş, dâhil edilme kriterlerini sağlayan 35 çalışma (6 tez, 29 makale) elde edilmiştir. Etki büyüklüklerinin hesaplanmasında Hedges's g ve analizlerde rastgele etkiler modeli tercih edilmiştir. Analiz sonucunda ortalama etki büyüklüğü (g=0.979, 95% CI:0.771-1.188, p<0.001) sınıflamaya göre yüksek düzey bulunmuştur. Buna göre, TGA stratejisi öğrencilerin fen başarısını artırmakla birlikte yüksek düzeyde etkilemektedir. Çalışmalar arasındaki farklılıklar analog ANOVA ve meta-regresyon analizleri ile belirlenmiştir. TGA stratejisinin öğrencilerin fen başarısı üzerindeki etkisi bilim alanı ve öğretim kademesi moderatörlerine göre anlamlı farklılıklar gösterirken, uygulanma şekli moderatörüne göre anlamlı bir farklılık göstermemiştir. Uygulama süresi ve yayın yılı moderatörlerinin TGA stratejisinin fen başarısı üzerindeki etkisinin anlamlı birer yordayıcıları olmadığı ortaya koyulmuştur. Bu sonuçlardan yola çıkarak araştırmacı ve uygulayıcılara bazı önerilerde bulunulmuştur.

Anahtar kelimeler: Tahmin-gözlem-açıkla, fen eğitimi, akademik başarı, meta-analiz

Geliş tarihi/Received: 18.10.2024 Kabul Tarihi/Accepted: 03.12.2024 Makale Türü: Araştırma Makalesi

---

[1] Assoc. Prof., Yozgat Bozok University, Primary School Department, zeynepko.unlu@yobu.edu.tr, 0000-0003-3627-1809

Atıf için/To cite: Koyunlu Ünlü, Z. (2024). Fen eğitiminde tahmin-gözlem-açıkla stratejisinin akademik başarıya etkisi: Bir meta analiz çalışması. *Van Yüzüncü Yıl Üniversitesi Eğitim Fakültesi Dergisi, 21*(3), 893-920. https://doi.org/10.33711/yyuefd.1570041

Introduction

Following the transition from the classical approach to the constructivist approach in science education, student-centered learning methods and techniques have come to the fore. In constructivist learning, the new information to be taught is built onto the existing knowledge of the students (Matthews, 2002). Constructing concepts interactively in a social context is particularly important in the teaching of science. In classroom environments where students are active, expressing their ideas and comparing their own ideas with those of their peers enables them to construct knowledge (Kearney, 2004). Predict-observe-explain (POE) is one of the student-centered strategies under the umbrella of inquiry-based learning, which is in harmony with social constructivism and allows students to become responsible for their own learning. The POE strategy is a further development of a technique implemented at the University of Pittsburgh in the 1980s, known as demonstration, observation, and explanation (DOE) (Kearney, 2004). POE, which is based on classical research procedures, essentially includes the steps of forming a hypothesis, expressing the justifications for that hypothesis, collecting data to test the hypothesis, and discussing the results (Kearney, 2004; White, 1988). In POE, students first make a justified prediction before an experiment or activity to be carried out, and then they make observations about the experiment or activity. Finally, they explain whether there is a difference between their predictions and observations (White, 1988; White & Gunstone, 1992). Closed-ended “cookbook” laboratory experiments, in which students are given the steps to be followed and the aim is to verify information, do not facilitate in-depth learning and only allow students to perform the assigned task (Hofstein & Lunetta, 2004). In contrast to closed-ended experiments, POE is particularly used in experiments in which scientific concepts are constructed (Bulunuz & Bulunuz, 2017; Erdem Özcan & Uyanık, 2022).

The POE strategy, has been utilized in science education for several decades (Gunstone & White, 1981; White & Gunstone, 1992). Many experimental studies have been conducted on the effects of the POE strategy on science achievement. Experimental studies have been carried out particularly intensively in recent years. However, these studies differ from each other due to the different independent variables they include and their results do not seem to be consistent with each other (e.g., Çalış & Özkan, 2022; Tetik, 2019). Conducting a meta-analysis study by combining the results of those previous experimental studies will help in understanding the general results. In the literature, there have been two meta-analysis studies of the POE strategy to date. In the meta-analysis study performed by Gustina et al. (2023), 70 studies conducted in the fields of science and mathematics between 2013 and 2022 were included in the analysis. The researchers found that POE is more effective on learning outcomes than critical thinking skills, that it is highly effective at the senior high school level while it has rather low effects at the elementary school level, that it is more effective in mathematics than in science, and that the results of studies conducted between 2013 and 2017 were more effective than those of studies conducted between 2018 and 2022. In the second meta-analysis, Nurshafara (2022) investigated the effects of POE on physics learning outcomes. The results showed that POE was effective in the cognitive and affective domains at the junior and senior high school levels in studies conducted in Sumatra, Indonesia. Meta-analysis studies on the POE strategy (Gustina et al., 2023; Nurshafara, 2022) have indicated the need for more comprehensive meta-analysis. In recent years, especially in studies conducted on the effects of the POE strategy on academic achievement in science education, some variables have been common across different studies. In these studies, the POE strategy has been implemented alone or together with the support of technology; in different fields of science such as physics, chemistry, biology, astronomy, and geology; at various educational levels such as primary school, middle school, high school, and university; and for periods of time ranging from a week to a semester. The existence of these differences among studies is one of the most important reasons for conducting the present meta-analysis study. While expanding further on the results of studies conducted to date, it is important to determine the effectiveness of the POE strategy, which is particularly used when scientific concepts are being constructed, for science achievement and to analyze its effects while taking into account different moderators such as field of science, implementation type, level of education, implementation time, and publication year. Examining the effects of these moderating variables on academic achievement may help produce a general perspective while providing ideas for researchers, teachers, curriculum developers, and policymakers. Furthermore, this meta-analysis may contribute to the development of new course designs and the improvement of current courses. In this respect, answers were sought to the following questions in the present study:

(1) What is the effect of the POE strategy on students' science achievement?

(2) Does the effect of the POE strategy on students' science achievement differ significantly according to the field of science, implementation type and level of education?

(3) Are the implementation time and year of publication significant predictors of the effect of the POE strategy on students' science achievement?

POE Strategy

The POE strategy consists of three stages: prediction, observation, and explanation. In the introductory part of a lesson plan, students' attention is drawn to the topic to be covered, they are motivated, and their prior knowledge is identified. This is also the case in the first stage of POE, namely prediction (P). In this stage, students are asked to make justified predictions about the topic to be explained, an experiment, or an event (White & Gunstone, 1992). Students' ideas, beliefs, misconceptions, and incomplete or erroneous knowledge can be identified while collecting their justified predictions (White & Gunstone, 1992). What is important in the prediction stage is justification. Making predictions without justification is similar to not showing the connections in concept maps. In such a case, "showing that you understand," which is the most important feature of POE, is not taken into account. It is important to ask open-ended questions appropriate to the level of the student in this stage, where justifications can be expressed (Kearney, 2004). Encouraging students to document their predictions by writing them down will also improve their written communication skills (Atasoy, 2004; Coe, 1993; Kearney, 2002, 2004; Ross & Munby, 1991). In the prediction stage, students can be asked open-ended questions that do not limit their thoughts or choices (Atasoy, 2004). Özçelik (2019) supported the prediction stage with concept cartoons reflecting more than one opinion. In the observation (O) stage, students conduct individual or group research or experiments about their predictions. Since the observation stage requires research, a lack of material may hinder the process (Kearney, 2004). However, the observation stage can be supported by instructional technologies such as animation, simulation, and video. Students can take notes about their observations and record data. Students' justified predictions may be correct or incorrect (White & Gunstone, 1992; Tao & Gunstone, 1997). Since observations are theory-laden, it is important to remember that students' observations are affected by their knowledge and the predictions they make (Kearney, 2002; Liew & Treagust, 1998; White & Gunstone, 1992; Yaman, Ayas, & Çalık, 2019). If there are contradictions between students' predictions and observations, they are expected to resolve them in the explanation (E) stage, where they have the opportunity to revise their ideas. Based on the students' explanations, the teacher can conduct diagnostic and formative assessments. In this sense, the POE strategy also provides an opportunity for teachers to get to know their students (Kearney, 2002, 2004; Yaman, Ayas, & Çalık, 2019).

Moderator Variables

POE strategy has been widely implemented in science fields such as physics (Akpınar, 2014; Chen et al., 2020; Chen, 2022), chemistry (Acar Şeşen, 2013; Coştu, 2008; Yaman & Ayas, 2015), biology (Lucas et al., 2022), geology (James et al., 2022) and astronomy (Hsiao et al., 2017). In addition, it has also been used in the fields of mathematics (Yang & Chen, 2023) and psychology (Guerrero et al., 2022). In the process of implementing the POE strategy, some field of science such as physics, chemistry, and biology allow for direct observations and applications, while astronomy and earth science allow for indirect observations and applications. Therefore, determining in which field of science the use of the POE strategy is more effective on academic achievement has been seen as an important moderator variable.

In the literature, the POE strategy has been used both on its own (Erdem Özcan & Uyanık, 2022; Furqani et al., 2018; Karamustafaoğlu & Mamlok-Naaman, 2015) and with the support of technology (Akpınar, 2014; Chen et al., 2020; Fateen, 2020; Nyirahabimana et al., 2023; Yaman & Ayas, 2015). With the POE strategy, technology can be used as a replacement for difficult, costly, time-consuming, and dangerous experiments (Kearney, 2004). All or some of the stages of the POE strategy were supported by technology in previous studies. In that way, it was aimed to make abstract and complex scientific concepts concrete and comprehensible. For instance, Tüysüz and Özdemir (2024) implemented the traditional POE strategy in one of two groups of 9th graders taking a physics course and the POE strategy supported by computer simulations in the other group. The groups had similar outcomes for the prediction and observation stages. However, in the classroom where traditional POE was implemented, the teacher made explanations about the observations using visual elements such as drawings, pictures, and analogies, while with the POE strategy supported by computer simulations, the teacher acted as a guide in the explanation stage, enabling students to benefit from the visual and interactive features of computer simulations. It was concluded that the POE strategy enriched with simulations was more effective than traditional POE in increasing student achievement. Yaman and Ayas (2015) incorporated digital video clips, simulations, and animations into the POE strategy for lessons on acids and bases at the high school level. They used animations and simulations to eliminate students' misconceptions. Macroscopic events were observed via video clips and microscopic events were observed via simulations. Akpınar (2014) investigated the effects of animation-supported POE and normal instruction on the learning of concepts in teaching about electricity in elementary school. For both approaches, experiments were conducted on the subject of static electricity. Subsequently, in the experimental group, dynamic and interactive animations were implemented together with the POE strategy. The prediction and observation stages of POE were supported with animations. The results suggested that the students in the experimental group, which was taught using POE supported by interactive animations, learned concepts related to electricity better. Chen et al. (2020) concluded that supporting game-based learning with POE in middle school physics contributed positively to the students' conceptual understanding. In the implementation process, the observation stage of the POE strategy was supported with games. As previously mentioned, there are studies in the literature confirming that the POE strategy is more effective when it is supported by technology. Therefore, the type of POE implementation (only POE or technology-supported POE) was also considered as an important variable that could affect academic achievement and was accordingly selected as one of the moderating variables.

POE strategy has been used at the preschool (Hsu et al., 2011), elementary school (Erdem Özcan & Uyanık, 2022), middle school (Chen et al., 2020; Chen, 2022), high school (Çinici et al., 2011; Yaman & Ayas, 2015), and university (James et al., 2022; Lucas et al., 2022) levels, especially in the teaching and learning of scientific concepts. In one of the previously conducted meta-analysis studies, it was concluded that the POE strategy had a very limited effect at the elementary school level (Gustina et al., 2023), and in another meta-analysis, the POE strategy was shown to be effective at the middle school and high school levels (Nurshafara, 2022). Although researchers have stated that the POE strategy is suitable for elementary school students (Erdem & Özcan Uyanık, 2022; Palmer, 1995), the differences in the effects of this strategy according to education level remain to be clarified. Therefore, level of education was considered as a moderating variable in the present meta-analysis study.

In experimental studies where the POE strategy was used, implementation time ranged from one week (e.g., Karpin et al., 2014) to a period of 12 weeks (Ayvacı & Durmuş, 2016). Increasing the implementation time may increase academic achievement (White, 1988). Therefore, intervention time was considered as one of the moderating variables. Another moderator examined within the scope of this research is the publication year. The widespread use of the constructivist approach and technology in education after the 2000s, and distance education during the COVID-19 period have made the predictive value of the publication year on the effect of the POE strategy on academic achievement a matter of curiosity. However, since the moderators of intervention time and publication year were considered as continuous variables in the present study, no categorizations were performed for these variables while analyzing the effect of the POE strategy on academic achievement (Hedges & Olkin, 1985).

Method

In this study, the effect of POE on students' science achievement was analyzed by meta-analysis. Meta-analysis is a method that combines statistical findings obtained with different calculations (Borenstein et al., 2021). In the selection and analysis of the studies, a 3-step procedure was followed, similar to the methods suggested by Card (2012), Field and Gillett (2010), and Glass et al. (1981). These steps were the selection of studies, the application of a coding strategy, and data analysis.

Selection of Studies

The search for relevant studies was carried out in two stages. In the first stage, the keywords "predict," "observe," and "explain" were used, and in the second stage, the keywords "prediction," "observation," and "explanation" were used. The Web of Science (WoS), Scopus, and Education Resources Information Center (ERIC) databases were utilized to search for articles and the ProQuest Dissertations & Theses Global (PQDT) database was used to search for theses.

The criteria applied in selecting the studies included in the meta-analysis were as follows: 1) studies related to POE and scientific achievement, 2) open access full-text studies published between 2003 and 2023, 3) studies published in English or Turkish, 4) studies published in thesis or article format, 5) studies that included POE implementation, and 6) studies that had sufficient data for the calculation of effect size.

Due to the different characteristics of the databases, a standardized search was not performed and different Boolean operators were used in the process. The searching was completed on January 10, 2024. The keywords identified in the databases and the way in which the searching was conducted according to the inclusion criteria are explained in detail below:

• In the search section of the PQDT database, keywords were entered with the NOFT code (predict AND observe AND explain) in the first stage and with NOFT(prediction AND observation AND explanation) in the second stage, ensuring that they were found in all studies anywhere except the full text. All studies were filtered as full text, year range 2003-2023, and publication languages English and Turkish. As a result of these search, a total of 411 studies were identified, including 117 in the first stage and 294 in the second stage.

• In the simple search section of the WoS database, keywords were entered as predict AND observe AND explain in the first stage and prediction AND observation AND explanation in the second stage; while searching in the WoS Core Collection, editions SCI-E, SSCI, AHCI, and ESCI, the search field was specified as topic. All studies were filtered as publication years 2003-2023; document type article; WoS categories Education-Educational Research, Education-Scientific Disciplines, and Education-Special; and publication languages English and Turkish. As a result of these searches, a total of 225 studies were identified, including 190 in the first stage and 35 in the second stage.

• In the advanced search section of the Scopus database, keywords were entered with the TITLE-ABS-KEY code (predict AND observe AND explain) in the first stage and the TITLE-ABS-KEY code (prediction AND observation AND explanation) in the second stage. All studies were filtered as year range 2003-2023, subject area Social Sciences, document type article, and publication languages English and Turkish. As a result of these searches, a total of 189 studies were identified, including 101 in the first stage and 88 in the second stage.

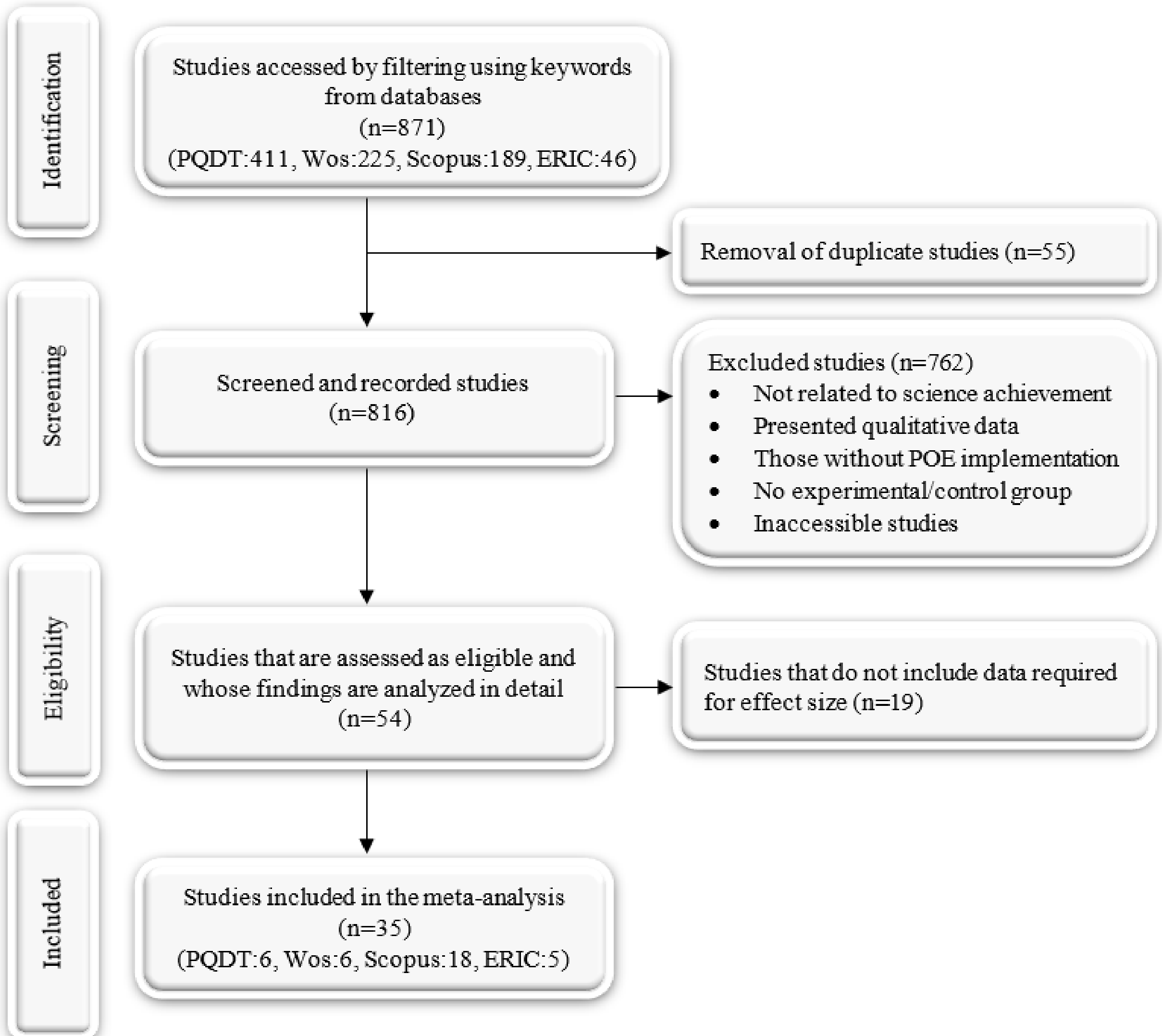
• In the simple search section of the ERIC database, keywords were entered as predict AND observe AND explain in the first stage and prediction AND observation AND explanation in the second stage. All studies were filtered as full text, publication dates 2003-2023, and publication type journal articles. As a result of these searches, a total of 46 studies were identified, including 30 in the first stage and 16 in the second stage.

The reason for conducting the searches using only the keywords “predict,” “prediction,” “observe,” “observation,” “explain,” and “explanation,” excluding words related to science achievement, was to obtain as many studies as possible related to the research problem and avoid overlooking any relevant studies. During the searches, publications produced from conference papers, project reports, and theses were frequently encountered. Due to their lack of data, conference papers and project reports, publications produced from theses, and studies that did not meet any of the inclusion criteria were excluded. In cases where the same study was found in more than one database, the study was taken from the first database in which it was found and subsequent appearances of it were ignored. A detailed description of the review process is critical in a meta-analysis for the transparency, reliability, and reproducibility of the research (Moher et al., 2009; Sarkis-Onofre et al., 2021).

The review process of the present study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al., 2021). The PRISMA flowchart is shown in Figure 1.

Figure 1

Screening Process PRISMA Flowchart



As can be seen in Figure 2, a total of 438 studies (PQDT: 117, WoS: 190, Scopus: 101, ERIC: 30) were found at the end of the first stage and 433 studies (PQDT: 294, WoS: 35, Scopus: 88, ERIC: 16) were found at the end of the second stage of searches conducted with the keywords, limitations, and inclusion criteria described above, totaling 871 studies. After the removal of 55 duplicate studies from different databases, 816 studies were examined according to their titles, abstracts, and methods. It was decided to exclude studies that were not related to science achievement, that presented qualitative data, that did not include POE implementation, that lacked experimental/control groups, or that were inaccessible. After excluding 762 studies, the remaining 54 studies were evaluated as suitable for the meta-analysis and their findings were examined in detail for effect size. It was decided to exclude 19 studies that did not have sufficient data for the calculation of effect size. Finally, a total of 35 studies, including 6 from PQDT, 6 from WoS, 18 from Scopus, and 5 from ERIC, were included in the meta-analysis.

Coding Strategy

A coding form was created by the author to be used in the coding process. This form included the following information about the studies: 1) study number, 2) author(s) of the study, 3) publication year of the study, 4) title of the study, 5) field of science for which POE was implemented, 6) implementation type of POE, 7) level of education, 8) implementation time of POE, and 9) sample numbers, arithmetic averages, standard deviations, and other data for the calculation of effect size.

The coding was carried out by two coders, one of whom was an expert in meta-analysis and the other the author herself. The coders first read the titles and abstracts of the studies that had been obtained and then read the contents of the studies. Each of the studies that were deemed appropriate by the coders were recorded separately on their computers using the coding form. The recorded studies were compared from time to time, and inconsistencies, if any, were resolved through a mutual exchange of views. The coding was continued until full agreement was achieved between the coders. Cohen's kappa coefficient was used to determine intercoder reliability. There was no disagreement between the coders until the last stage of the review process, so Cohen's kappa was not calculated. In the last stage, 4 of the 54 studies whose findings were analyzed had disagreement and 50 had consensus. The coders re-evaluated whether the studies for which there was disagreement had the necessary data for the calculation of effect size. It was decided to exclude 2 of the 4 studies for which there was disagreement due to missing data and to include those of Özçelik (2019) and Hsiao et al. (2017) in the meta-analysis. Cohen's kappa coefficient was calculated according to the studies with agreement and disagreement and found to be 0.839. This value is greater than 0.80, indicating a high level of agreement between the coders (Cohen et al., 2002).

Since 3 of the 35 studies included multiple experimental groups, it was decided to code the studies of Çinici et al. (2011) and Özçelik (2019) as two independent studies and that of Hsiao et al. (2017) as three independent studies. The characteristics of the studies included in the meta-analysis are given in Table 1. As can be seen in Table 1, the publication years of the studies ranged between 2008 and 2023 despite the broader range limit used in the inclusion criteria. It can be concluded that such studies have intensified in recent years. The studies were categorized according to the fields of astronomy, physics, chemistry, biology, chemistry-physics, and geology. In some studies, POE was applied together with digital games (Chen et al., 2020; Hsu et al., 2011), simulations (Chen et al., 2013; Fateen, 2020), animations (Akpınar, 2014), multimedia technologies (Nyirahabimana et al., 2023), computers (Karslı Baydere, 2021; Yaman & Ayas, 2015), and websites, videos, and flash animations (Hsiao et al., 2017). For this reason, the studies were categorized into two groups according to the implementation type of POE: studies in which POE was used alone and studies in which it was supported by technology. The samples of the studies were grouped according to the level of education: preschool, elementary school (grades 1-4), middle school (grades 5-8), high school (grades 9-12), and university (UNESCO, 2012). The implementation time of POE was determined in weeks as stated in the studies. However, in the studies of Bulunuz and Bulunuz (2017), Chen (2022), Coştu (2008), Furqani et al. (2018), Harman and Yenikalaycı (2022), Hsu et al. (2011), James et al. (2022), Lucas et al. (2022), and Zhao et al. (2021), the implementation time was not clearly stated in weeks. As can be seen in Table 1, that information was accordingly left blank during coding. Although not specified in the table, the sample sizes of the studies varied between 12 and 365. The total sample size of the combined studies was 2840.

Van Yüzüncü Yıl University Journal of Education, 2024; 21(3), p. 893-920. DOI: 10.33711/yyuefd.1570041

Table 1

Characteristics of the Studies Included in the Meta-Analysis

ID	Author(s), year	Field of science	Implementation type of POE	Level of education	Implementation time (week)
1	Akpınar, 2014	Physics	Technology supported POE	Primary school	10
2	Ayvacı & Durmuş, 2016	Physics	POE	University	12
3	Banawi et al., 2019	Chemistry	POE	University	4
4	Bilen & Köse, 2012	Biology	POE	University	4
5	Bolat & Karamustafaoğlu, 2021	Physics	POE	Middle school	3
6	Bulunuz & Bulunuz, 2017	Physics	POE	High school	
7	Chen et al., 2013	Physics	Technology supported POE	University	1
8	Chen et al., 2020	Physics	Technology supported POE	Middle school	2
9	Chen, 2022	Physics	Technology supported POE	Middle school	
10	Coştu, 2008	Chemistry	POE	High school	
11	Coştu, 2021	Chemistry & physics	POE	University	9
12	Çalış & Özkan, 2022	Physics	POE	Middle school	6
13	Çıngıl Barış, 2022	Biology	POE	University	6
14	Çinici et al., 2011_1	Biology	POE	High school	4
15	Çinici et al., 2011_2	Biology	POE	High school	4
16	Erdem Özcan & Uyanık, 2022	Chemistry	POE	Primary school	8
17	Fateen, 2020	Physics	Technology supported POE	University	1
18	Furqani et al., 2018	Physics	POE	Middle school	
19	Harman & Yenikalaycı, 2022	Physics	POE	University	
20	Hsiao et al., 2017_1	Astronomy	POE	Primary school	5
21	Hsiao et al., 2017_2	Astronomy	Technology supported POE	Primary school	5
22	Hsiao et al., 2017_3	Astronomy	POE	Primary school	5
23	Hsu et al., 2011	Physics	Technology supported POE	Preschool	
24	James et al., 2022	Geology	Technology supported POE	University	
25	Kahraman, 2023	Chemistry	Technology supported POE	University	4
26	Karamustafaoğlu & Mamlok-Naaman, 2015	Chemistry	POE	University	3
27	Karpin et al., 2014	Chemistry	POE	High school	1
28	Karslı Baydere, 2021	Chemistry	Technology supported POE	Middle school	2
29	Kibirige et al., 2014	Chemistry	POE	High school	5
30	Lucas et al., 2022	Biology	Technology supported POE	University	
31	Nyirahabimana et al., 2023	Physics	Technology supported POE	University	6
32	Özçelik, 2019_1	Physics	POE	Middle school	4
33	Özçelik, 2019_2	Physics	POE	Middle school	4
34	Özkan, 2022	Physics	POE	Middle school	5
35	Tetik, 2019	Chemistry	POE	High school	4
36	Tokay, 2022	Chemistry	POE	High school	4
37	Wiyarsi et al., 2021	Chemistry	POE	High school	6
38	Yaman & Ayas, 2015	Chemistry	Technology supported POE	High school	5
39	Zhao et al., 2021	Physics	POE	Middle school	

Data Analysis

The free trial version of the Comprehensive Meta-Analysis (CMA) program was used for publication bias control, calculation of effect size values, heterogeneity testing, and moderator analyses (Borenstein et al., 2014). This program was preferred because it can easily combine and calculate data in different categories obtained from different studies.

Publication bias is the outcome of significant results being more likely to be published than statistically insignificant findings (Dickersin, 2005). This causes the calculated average effect size to be larger than the actual value (Card, 2012). Due to this problem, it is necessary to determine whether the studies included in a meta-analysis are impacted by publication bias or not. The methods used in this study for identifying publication bias were as follows: 1) the funnel plot method, 2) classic fail-safe N method, 3) Orwin's fail-safe N method, 4) Egger's regression test, and 5) Duval and Tweedie's trim-and-fill method.

When there is a study or studies with a sample size smaller than 20 among the papers included in a meta-analysis, Hedges' g can be used instead of Cohen's d in the calculation of effect sizes (Borenstein et al., 2021). In the analysis conducted for the present study, Hedges' g was preferred due to the presence of studies with sample sizes smaller than 20 (Bolat & Karamustafaoglu, 2021; Furqani et al., 2018; Yaman & Ayas, 2015). There are many classifications in the literature for effect sizes and levels. In this study, Thalheimer and Cook's (2002) classification was used. The ranges and levels of Hedges' g in this classification are as follows: $0.00 \leq g < 0.15$, ignored; $0.15 \leq g < 0.40$, low; $0.40 \leq g < 0.75$, medium; $0.75 \leq g < 1.10$, high; $1.10 \leq g < 1.45$, very high; $1.45 \leq g$, excellent.

Two models, the fixed effect model and the random effects model, are used to combine the effect sizes obtained from different studies. In meta-analyses, the average effect size will vary according to the selected model. The average effect size is calculated according to the random effects model if the effect sizes of the studies show a heterogeneous distribution and according to the fixed effect model if they do not (Cooper et al., 2009). In high-quality meta-analysis studies, the model being used is specified in advance (Borenstein et al., 2021). Furthermore, it is recommended to use the random effects model for meta-analysis studies (Field & Gillett, 2010). In this study, the average effect size was calculated according to the random effects model for reasons such as the populations of the studies not being the same and the data collection tools being different. This was also supported by heterogeneity test analysis results (Konstantopoulos & Hedges, 2019). Cochran's Q test was used to determine the difference between effect sizes and the I2 statistic was used to determine the level. A Cochran Q value greater than the value in the chi-square table (critical value) and a p significance value less than 0.05 indicate that effect sizes are heterogeneously distributed (Hedges & Olkin, 1985). An I2 statistic value greater than 50% indicates a sufficient level of heterogeneity, while a value greater than 75% indicates a high level of heterogeneity (Higgins et al., 2003). When there is a heterogeneous distribution among effect sizes, possible causes are identified through moderators (Rodriguez et al., 2023). In this study, possible reasons for heterogeneity were sought through both categorical and continuous moderators. Analog to the ANOVA (Hedges, 1982) was conducted for the categorical moderators of field of science, implementation type, and level of education, while meta-regression (Hedges & Olkin, 1985) was applied for the continuous moderators of publication year and implementation time.

Findings

Publication Bias

Publication bias was investigated using the funnel plot, classic fail-safe N, Orwin's fail-safe N, Egger's regression, and Duval and Tweedie's trim-and-fill methods. Figure 2 shows the distribution of effect sizes in a funnel plot.

Figure 2

Funnel Plot of Sstandard Error by Hedges's g

It can be seen in Figure 2 that most of the effect sizes are located within and on the upper side of the funnel plot. It can be argued that studies on the right or left side disrupt the symmetrical structure. The subjective interpretation of funnel plots necessitates additional methods to determine publication bias (Borenstein et al., 2021). Table 2 shows the publication bias findings based on the classic fail-safe N method.

Table 2

Publication Bias Findings of the Classic Fail-Safe N

z-value for observed studies	23.362
p-value for observed studies	0.000*
Alpha	0.050
Tails	2
z for alpha	1.959
Number of observed studies	39
Number of missing studies that would bring p-value to > alpha	5503

*p<0.001

In classic fail-safe N analysis, the number of missing studies that need to be included in the analysis for the significance to change is specified. This number, referred to as the fail-safe N

(FSN) value, is 5503, as can be seen in Table 2. This number is greater than 10 more than 5 times the number of available studies (n=39), or 205. This can be interpreted as signifying a low probability of publication bias (Rosenthal, 1991). Similarly, Orwin's FSN value was found to be 3859. This value indicates the number of missing studies needed to reduce Hedges' g below a specified value (0.01). The fact that this number is also large and that it would be difficult to reach 3859 papers confirms the conclusion that the likelihood of publication bias is low. Table 3 shows the findings of Egger's regression test for publication bias.

Table 3

Egger's Regression Intercept Ffindings of Publication Bias

Intercept	-0.651
Standard error	1.145
95% lower limit (2-tailed)	-2.973
95% upper limit (2-tailed)	1.669
t-value	0.568
df	37
p-value (1-tailed)	0.286
p-value (2-tailed)	0.572

Based on Egger's regression analysis, the null hypothesis of "there is no publication bias" was tested. As can be seen in Table 3, the 1-tailed p value (suggested) is 0.286 and the 2-tailed p value is 0.572. The result is not significant (t=0.568, p>0.05). Accordingly, it can be said that there is no publication bias (Egger et al., 1997). Table 4 shows the publication bias findings for Duval and Tweedie's trim-and-fill method (Duval & Tweedie, 2000).

Table 4

Duval and Tweedie's Trim and Fill Method Publication Bias Findings

	Studies trimmed	Point estimate	Lower limit	Upper limit	Q value
Observed values		0.979	0.771	1.188	259.418
Adjusted values	3	1.053	0.845	1.262	314.025

As shown in Table 4, the average effect size value calculated according to the random effects model is 0.979, and the average effect size value calculated with the 3 missing studies as described above is 1.053. The difference between the observed and adjusted average effect sizes (0.074) is less than 20%, indicating that there is no publication bias (Vevea et al., 2019).

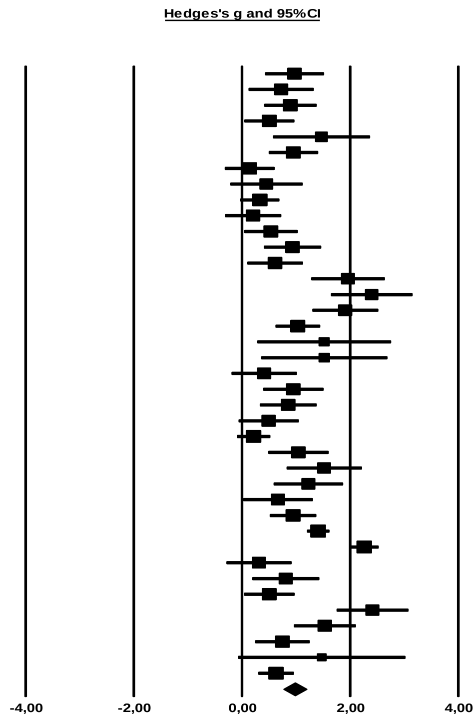
Average Effect Size and Heterogeneity Test

For each of the included studies, Hedges' g, standard error, variance, 95% confidence interval lower limit and upper limit, z, and p values and the distribution of effect sizes are shown in Figure 3.

Figure 3

Forest Plot of Studies Included in Meta-Analysis

Study name	Hedges's g	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Akpinar, 2014	0,972	0,277	0,077	0,429	1,515	3,509	0,000
Ayvaci & Durmus, 2016	0,726	0,306	0,094	0,126	1,326	2,371	0,018
Banawi et al., 2019	0,895	0,245	0,060	0,414	1,375	3,649	0,000
Bilen & Kose, 2012	0,506	0,235	0,055	0,046	0,966	2,158	0,031
Bolat & Karamustafaoglu, 2021	1,471	0,456	0,208	0,576	2,365	3,222	0,001
Bulunuz & Bulunuz, 2017	0,951	0,231	0,054	0,497	1,404	4,109	0,000
Calis & Ozkan, 2022	0,144	0,233	0,055	-0,314	0,602	0,617	0,537
Chen et al., 2013	0,452	0,339	0,115	-0,213	1,117	1,332	0,183
Chen et al., 2020	0,331	0,183	0,033	-0,027	0,690	1,812	0,070
Chen, 2022	0,206	0,264	0,070	-0,312	0,724	0,779	0,436
Cingil Baris, 2022	0,536	0,251	0,063	0,043	1,029	2,131	0,033
Cinici et al., 2011_1	0,934	0,269	0,072	0,408	1,461	3,476	0,001
Cinici et al., 2011_2	0,613	0,261	0,068	0,101	1,124	2,349	0,019
Costu, 2008	1,961	0,345	0,119	1,284	2,638	5,679	0,000
Costu, 2021	2,398	0,383	0,147	1,647	3,148	6,261	0,000
Erdem Ozcan & Uyanik, 2022	1,910	0,309	0,095	1,305	2,516	6,187	0,000
Fateen, 2020	1,032	0,209	0,044	0,622	1,442	4,935	0,000
Furqani et al., 2018	1,520	0,629	0,396	0,287	2,753	2,415	0,016
Harman & Yenikalayci, 2022	1,523	0,593	0,352	0,360	2,686	2,566	0,010
Hsiao et al., 2017_1	0,412	0,306	0,094	-0,189	1,012	1,344	0,179
Hsiao et al., 2017_2	0,950	0,283	0,080	0,396	1,504	3,360	0,001
Hsiao et al., 2017_3	0,855	0,267	0,071	0,332	1,377	3,206	0,001
Hsu et al., 2011	0,494	0,283	0,080	-0,061	1,048	1,746	0,081
James et al., 2022	0,215	0,156	0,024	-0,091	0,521	1,380	0,168
Kahraman, 2023	1,043	0,283	0,080	0,488	1,597	3,687	0,000
Karamustafaoglu & Mamlok-Naaman, 2015	1,521	0,354	0,125	0,828	2,214	4,303	0,000
Karpin et al., 2014	1,229	0,326	0,106	0,590	1,867	3,771	0,000
Karsli Baydere, 2021	0,667	0,327	0,107	0,026	1,308	2,038	0,042
Kibirige et al., 2014	0,944	0,217	0,047	0,518	1,370	4,346	0,000
Lucas et al., 2022	1,409	0,104	0,011	1,205	1,613	13,510	0,000
Nyirahabimana et al., 2023	2,262	0,134	0,018	1,999	2,524	16,893	0,000
Ozcelik, 2019_1	0,315	0,305	0,093	-0,283	0,912	1,033	0,302
Ozcelik, 2019_2	0,810	0,315	0,099	0,192	1,428	2,568	0,010
Ozkan, 2022	0,504	0,237	0,056	0,039	0,968	2,125	0,034
Tetik, 2019	2,413	0,337	0,113	1,753	3,073	7,164	0,000
Tokay, 2022	1,533	0,291	0,085	0,963	2,103	5,273	0,000
Wiyarsi et al., 2021	0,749	0,256	0,065	0,248	1,250	2,928	0,003
Yaman & Ayas, 2015	1,476	0,788	0,621	-0,068	3,020	1,873	0,061
Zhao et al., 2021	0,631	0,166	0,028	0,305	0,957	3,791	0,000
	0,979	0,106	0,011	0,771	1,188	9,205	0,000



As seen in Figure 3, the Hedges' g values obtained from the studies vary between 0.144 and 2.413. It was found that the Hedges' g value was highest for the study by Tetik (2019) at 2.413 and smallest for the study by Çalış and Özkan (2022) at 0.144. The effect size p values of the studies conducted by Çalış and Özkan (2022), Chen et al. (2020), Chen (2022), Hsiao et al. (2017), Hsu et al. (2011), James et al. (2022), Özçelik (2019), and Yaman and Ayas (2015) are not significant ($p>0.05$). All effect sizes are positive with different reliability intervals. According to Thalheimer and Cook's (2002) classification, there are 1 (2.6%) ignored, 4 (10.3%) low, 11 (28.2%) medium, 10 (25.6%) high, 3 (7.7%) very high, and 10 (25.6%) excellent effect sizes. The average effect size, related values, and heterogeneity test findings of the studies according to fixed and random effects models are given in Table 5.

Table 5

Average Effect Size and Relevant Values of the Studies Included in the Meta-Aanalysis, as well as Heterogeneity Test Findings

Model	k	Point estimate	Standard error	95% CI		z	p	Q	df	p	I^2
				Lower limit	Upper limit						
Fixed	39	0.999	0.039	0.923	1.075	25.725	0.000*	259.418	38	0.000*	85.352
Random	39	0.979	0.106	0.771	1.188	9.205	0.000*				

*p<0.001

As seen in Table 5, according to the fixed effect model, the average effect size is 0.999, the standard error is 0.039, the lower limit of the 95% confidence interval is 0.923, and the upper limit is 1.075 ($z=25.725$, $p<0.001$). According to the random effects model, the average effect size is 0.979, the standard error is 0.106, the lower limit of the 95% confidence interval is 0.771, and the upper limit is 1.188 ($z=9.205$, $p<0.001$). For both models, the average effect size value is at a high level according to Thalheimer and Cook's (2002) classification. This finding shows that the POE strategy has a high-level effect on students' science achievement according to both models.

When the heterogeneity test findings were analyzed, it was found that the p value was 0.000 and the Q value was 259.418. It is statistically significant that the calculated p value is less than 0.05 and the Q value is greater than the chi-square table value (53.383) at 38 degrees of freedom and a significance level of 0.05 ($Q>\chi^2$, $p<0.05$). Accordingly, the effect sizes show a heterogeneous distribution. The value of the I^2 statistic (85.352) is greater than 75%, which indicates a high level of heterogeneity (Higgins et al., 2003). It can be stated that approximately 85.35% of the variance between effect sizes is due to real differences in effect sizes and 14.65% is due to sampling error (Huedo-Medina et al., 2006; Li et al., 2021). Moderator analyses need to be conducted to explain such a high level of variation (Lipsey & Wilson, 2001).

Moderator Analyses

Analog to the ANOVA was conducted in line with the following question: "Does the effect of the POE strategy on students' science achievement differ significantly according to the field of science, implementation type, and level of education?" Analog to the ANOVA findings related to the moderators of field of science, implementation type of POE, and level of education are given in Table 6.

Table 6

Analog to the ANOVA Moderator Analysis Findings

Variables	Category	k	$\bar{g}$	SE	95% CI Lower limit	95% CI Upper limit	z	p	Q_B	df	p
Field of science	Astronomy	3	0.760	0.164	0.439	1.081	4.638	0.000*	42.466	5	0.000*
	Biology	5	0.825	0.231	0.372	1.278	3.570	0.000*			
	Chemistry	12	1.327	0.157	1.019	1.635	8.448	0.000*			
	Chemistry & physics	1	2.398	0.383	1.647	3.148	6.261	0.000*			
	Geology	1	0.215	0.156	-0.091	0.521	1.380	0.168			
	Physics	17	0.815	0.187	0.448	1.183	4.353	0.000*			
Implementation type of POE	POE	26	1.019	0.111	0.802	1.236	9.188	0.000*	0.056	1	0.551
	Technology supported POE	13	0.875	0.215	0.453	1.296	4.068	0.000*			
Level of education	High school	10	1.229	0.172	0.891	1.566	7.143	0.000*	17.497	4	0.002
	Middle school	10	0.515	0.105	0.308	0.721	4.878	0.000*			
	Preschool	1	0.494	0.283	-0.061	1.048	1.746	0.081			
	Primary school	5	1.015	0.229	0.565	1.464	4.425	0.000*			
	University	13	1.100	0.211	0.686	1.513	5.209	0.000*			

*p<0.001

Table 6 shows that the p value is 0.000 and the Q_B value is 42.466. The fact that the p value is less than 0.05 and the Q_B value is greater than the critical value (11.070) indicates that there is a significant difference between the groups ($Q_B>\chi^2$, $p<0.05$). According to these results, the effect of the POE strategy on students' science achievement differs significantly with respect to the moderator of field of science. The average effect size values are 0.760, 0.825, 1.327, 2.398, 0.215, and 0.815 for astronomy, biology, chemistry, chemistry-physics, geology, and physics, respectively. According to Thalheimer and Cook's (2002) classification, the POE strategy had a low effect on students' science achievement in geology; a high effect in astronomy, biology, and physics; a very high effect in chemistry; and an excellent effect in chemistry-physics. When the heterogeneity test findings for the implementation type of POE was analyzed, the p value was 0.551 and the Q_B value was 0.056. The fact that the p value is greater than 0.05 and the Q_B value is less than the critical value (3.841) indicates that there is no significant difference between the groups ($Q_B<\chi^2$, $p>0.05$). Accordingly, it can be concluded that different ways of implementing POE affected students' science achievement at similar levels. The average effect size values for POE and technology-supported POE were 1.019 and 0.875, respectively. Although there was no significant moderator, POE and technology-supported POE affected students' science achievement at a high level according to the classification. When the heterogeneity test findings for level of education were analyzed, it was found that the p value was 0.002 and the Q_B value was 17.497. The fact that the p value is less than 0.05 and the Q_B value is greater than the critical value (9.487) indicates that there is a significant difference between the groups ($Q_B>\chi^2$, $p<0.05$). Accordingly, the effect of the POE strategy on students' science achievement differs significantly according to the moderator of education level. The average effect size values for high school, middle school, preschool, elementary school, and university are 1.229, 0.515, 0.494, 1.015, and 1.100, respectively. The POE strategy had a very high effect on students' science achievement in high school and university, a high effect in elementary school, and a medium effect in middle school and preschool.

Meta-regression analyses were conducted in line with the following question: "Is the implementation time and year of publication a significant predictor of the effect of the POE strategy on students' science achievement?" The meta-regression analysis findings are given in Table 7.

Table 7

Meta-Regression Moderator Analysis Findings

Variable	k	B	SE	95% CI		z	p	Tau^2	R^2
				Lower limit	Upper limit				
Intervention time (week)	30	0.044	0.044	-0.042	0.130	1.000	0.318	0.268	0.040
Publication year	39	0.008	0.023	-0.038	0.055	0.350	0.725	0.277	0.005

Before starting the meta-regression analyses, linear regression assumptions were checked separately using IBM SPSS Statistics 26 (IBM Corp., 2019). First, the graphs of the variables were checked to see whether they showed a linear relationship, and then the normality values were checked to see whether the data were normally distributed (Delen & Şen, 2023). It was seen that the graphs showed linear relationships. When the kurtosis and skewness values of the variables were analyzed separately, it was seen that these values were between -2 and +2, thus meeting the normality assumptions (George & Mallery, 2010). Analyses regarding the moderators of implementation time and publication year were conducted separately with the available data, and the maximum likelihood method was used in the analysis according to the random effects model. As can be seen in Table 7, implementation time and year of publication were not significant predictors of the effect of the POE strategy on students' science achievement ($p>0.05$). In other words, it can be argued that the effect of POE on students' science achievement was not affected by changes in implementation time and publication year. Approximately 4% of the variance related to the effect of the POE strategy on students' science achievement is explained by the moderator of implementation time and approximately 5% by the moderator of publication year.

Discussion

In this study, which aimed to examine the effect of the POE strategy on achievement in science education by meta-analysis method, 39 independent effect size values were obtained from 35 individual studies. The analysis results of the specified methods were examined separately for possible publication bias. According to the findings, it can be concluded that there was no publication bias that could affect the validity of the analysis. In other words, publication bias was not an important factor affecting the average effect size. Although the p values of 8 studies included in the meta-analysis were not significant (Çalış & Özkan, 2022; Chen et al., 2020; Chen, 2022; Hsiao et al., 2017; Hsu et al., 2011; James et al., 2022; Özçelik, 2019; Yaman & Ayas, 2015), the average effect size was calculated as 0.979 (Hedges' g) according to the random effects model. This is a high-level value according to Thalheimer and Cook's (2002) classification. In other words, the POE strategy has a high-level effect on students' science achievement. This finding is consistent with those of previous meta-analyses examining the effect of the POE strategy on learning outcomes (Gustina et al., 2023; Nurshafara, 2022). Gustina et al. (2023) found that POE had a medium-level effect on students' science and math learning outcomes, while Nurshafara (2022) concluded that POE had a great effect (0.995) on physics learning outcomes. The differences of the present study from the previous meta-analyses are that it included only studies conducted in the field of science, addressed different moderators, and utilized international databases. In the first stage of the POE strategy, students are motivated by drawing their attention to the experiment or activity to be carried out. Since a connection is established between students' prior knowledge and the information to be learned, the information is learned through structuring and meaningful learning is thus provided. With the POE strategy, students have opportunities for discussion while learning science concepts (Coştu, 2008, 2021). Since the stages of POE are clear and understandable, it is easy for teachers to implement it. For this reason, from the first studies conducted using the POE strategy (Gunstone & White, 1981; White & Gunstone, 1992) to the most recent research (Tüysüz & Özdemir, 2024), it has been consistently observed that POE contributes positively to cognitive domains such as student achievement, conceptual change, and knowledge level.

As a result of this meta-analysis, it was seen that the moderator of science field impacted the effect of the POE strategy on students' science achievement. Studies in geology affected students' science achievement at a low level; those in astronomy, biology, and physics had high-level effects; those in chemistry had very high-level effects; and those in chemistry-physics affected science achievement at an excellent level. The fact that activities and experiments carried out in the fields of physics, chemistry, and biology can be done in a short time and can be repeated may make POE more effective in increasing student achievement in those fields. Experiments and activities in the field of geology are generally based on observation and investigation. Therefore, assuming that students will be less active in the process of experiments or activities in the field of geology, it can be suggested that the implementation of the POE strategy in the field of geology is less effective in increasing student achievement. In addition, the fact that most of the concepts are theoretical and include events and phenomena that have already occurred or will occur over a long period of time may cause difficulties in teaching the concepts and information in the field of geology. In fact, only one study in the field of geology (James et al., 2022) was included in this meta-analysis, and that study was supported by simulations and video demonstrations. Similarly, there was only one study in the field of chemistry-physics (Coştu, 2021) included in this meta-analysis. When those studies were excluded from the meta-analysis, the difference between the studies remained similar. Therefore, there is a need for more studies in astronomy, geology, chemistry-physics, and other combinations of different fields of science. The studies included in this meta-analysis were mostly conducted in the fields of physics, chemistry, and biology, which are the main branches of science. In this respect, it can be suggested that studies in other science fields are needed for future meta-analysis studies.

In 13 of the studies included in this meta-analysis, the POE strategy was supported by various technologies such as animations, simulations, videos, and digital games. For this reason, the implementation type of POE (POE or technology-supported POE) was determined as a moderator variable in affecting students' science achievement. POE and technology-supported POE affected students' science achievement at similarly high levels. Accordingly, it can be argued that POE is a powerful strategy in influencing students' science achievement on its own, without being supported by technology. Since the POE strategy is compatible with social constructivism (Kearney, 2004), it provides cognitive, affective, and psychomotor gains such as attracting interest, providing motivation and active participation, and learning by structuring knowledge. Although the use of technology may have made a difference in the POE stages by preventing mediocre teaching, it may not have changed the learning outcomes. It can be suggested that conducting a hands-on experiment in a computer environment and trying to draw students' attention with a video or animation instead of by asking questions would have equal effects. In other words, the goal is the same, but the means are different. This finding of the present study is incompatible with the results of Tüysüz and Özdemir (2024), who concluded that the implementation of the POE strategy enriched with simulations was more effective than POE alone in increasing student achievement. However, the results of studies in the literature comparing the effects of technology and hands-on experiments on student achievement showed that computerized experiments involving animation and simulation were as effective as hands-on experiments (Evangelou & Kotsis, 2019; Zacharia & Olympiou, 2011). This inconsistency in the literature may be due to differences in the implementation of the POE strategy. Furthermore, this finding indicates the need for more research on the impact of implementing the POE strategy alone and with the support of technology.

The studies included in this meta-analysis were also examined according to the level of education. The effect of POE on students' science achievement differs significantly according to this moderator. The POE strategy had a very high effect on students' science achievement in high school and university, a high effect in elementary school, and a medium effect in middle school and preschool. There was only one study conducted at the preschool level (Hsu et al., 2011) included in this meta-analysis. When that study was excluded from the meta-analysis, the difference between the studies remained similar. This finding of the present study is similar to the results of Gustina et al. (2023) and Nurshafara (2022) regarding the effectiveness of the POE strategy at high school level. However, it is inconsistent with the finding of Gustina et al. (2023) that POE has a very low effect on student achievement at the level of elementary school. This may be due to the fact that Gustina et al. (2023) included studies in the fields of mathematics and natural sciences in their meta-analysis. In the present meta-analysis, only studies in the field of science education were included. In the present meta-analysis, implementation of the POE strategy in elementary school was found to be highly effective. Erdem and Özcan Uyanık (2022) stated that implementation of POE at the elementary school level is fun and intriguing and provides permanent learning. Since students in elementary school tend to explain their thoughts through verbal communication, Palmer (1995) argued that it is more effective to apply the POE strategy at this level rather than in middle or high school.

The results of this study also showed that the effect of the POE strategy on students' science achievement was not affected by changes in the implementation time or publication year. Although it can be seen that these studies have increased in recent years, the publication years of the studies included in this meta-analysis varied between 2008 and 2023. In this regard, Gustina et al. (2023) concluded that the POE strategy was effective on critical thinking and learning outcome in studies conducted between 2013-2017 at a medium level and in studies conducted between 2018-2022 at a low level. The researchers stated that this situation is likely to be due to COVID-19. The implementation time of the studies varied between 1 and 12 weeks, with an average of 4.8 weeks. According to the results of this research, it can be claimed that there is no difference between short-term and long-term implementation of the POE strategy for student achievement.

Limitations and Suggestions for Future Studies

The first limitation of this meta-analysis is that only studies in Turkish and English were examined. Therefore, in future meta-analysis studies, the effect of the POE strategy on science achievement could be examined with the review of studies published in different languages by a team of expert researchers. The moderator variables of this study constitute another limitation. The moderator variables were limited to field of science, level of education, implementation type, implementation time, and year of publication. In this context, meta-analysis studies on the POE strategy could be conducted using different moderators. The year range of the included studies and the databases searched are other limitations of this meta-analysis study.

Within the scope of this study, the effect of the POE strategy on learning outcomes such as conceptual understanding, academic achievement, and conceptual change was addressed as science achievement. Accordingly, it was found that the effect of POE on science achievement was high. Based on this result, the POE strategy could be integrated into science lessons in order to understand and construct concepts in the field of science correctly. Experimental research on the effectiveness of the POE strategy in the fields of geology and astronomy at preschool and elementary school levels should be conducted, since there is a limited number of experimental studies in geology and astronomy at those levels. The POE strategy could be implemented in long-term research while combining different science fields. Meta-analysis studies could be conducted on the effects of POE on different cognitive and affective outcomes. Qualitative studies on the POE strategy could be systematically examined and meta-synthesis studies could be conducted. In particular, meta-synthesis studies that explain in detail how POE can be implemented in classrooms would be useful for teachers and academics who are practitioners in the field.

Ethics Committee Permission Information: This study does not involve humans and/or animals; for this reason, no ethics approval was involved in the writing of this paper.

Author Conflict of Interest Information: The author declared that there is no potential conflict of interest. No funding was received for conducting this study.

Statement of Contribution Rate: Since this study has a single author, the contribution rate is 100%.

Acknowledgement: The author would like to thank Dr. Veli ÜNLÜ for his assistance in the meta-analysis process.

References

*Studies included in the meta-analysis

Acar Şeşen, B. (2013). Diagnosing pre-service science teachers' understanding of chemistry concepts by using computer-mediated predict-observe-explain tasks. *Chemistry Education Research and Practice, 14*(3), 239-246. https://doi.org/10.1039/C3RP20143K

*Akpınar, E. (2014). The use of interactive computer animations based on POE as a presentation tool in primary science teaching. *Journal of Science Education and Technology, 23*(4), 527-537. https://doi.org/10.1007/s10956-013-9482-4

Atasoy, B. (2004). *Science learning and teaching.* Asil Yayıncılık.

*Ayvacı, H. Ş., & Durmuş, A. (2016). Effect of laboratory activities based on "predict-observe-explain (POE)" method on pre-service science teachers' academic achievement on "heat and temperature" subject. *Pamukkale University Journal of Education, 39*(39), 101-118. http://dx.doi.org/10.9779/PUJE742

*Banawi, A., Sopandi, W., Kadarohman, A., & Solehuddin, M. (2019). Prospective primary school teachers' conception change on states of matter and their changes through predict-observe explain strategy. *International Journal of Instruction, 12*(3), 359-374. https://doi.org/10.29333/iji.2019.12322a

*Bilen, K., & Köse, S. (2012). An effective concept teaching strategy: Prediction-observation explanation (POE) "growth and development in plant". *Pamukkale University Journal of Education, 31*(31), 123-136.

*Bolat, A., & Karamustafaoğlu, S. (2021). Teaching mass and weight concepts: Prediction observation-explain. *Milli Eğitim Dergisi, 50*(230), 663-687. https://doi.org/10.37669/milliegitim.702128

Borenstein, M., Hedges, L., Higgins, J., & Rothstein, H. (2014). *Comprehensive meta-analysis* (Version 3.3.070) [Computer software]. Biostat. https://www.metaanalysis.com

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2021). *Introduction to meta analysis* (2nd ed.). John Wiley & Sons. https://doi.org/10.1016/b978-0-12-209005 9.50005-9

*Bulunuz, N., & Bulunuz, M. (2017). Effect of formative assessment-based instruction on high school students' conceptual understanding of balance and torque. *Journal of Inquiry Based Activities, 7*(1), 21-33.

Card, N. A. (2012). *Applied meta-analysis for social science research*. The Guilford Press.

*Chen, C. H., Huang, K. & Liu, J. H. (2020). Inquiry-enhanced digital game-based learning: Effects on secondary students' conceptual understanding in science, game performance, and behavioral patterns. *The Asia-Pacific Education Researcher, 29*(4), 319-330. https://doi.org/10.1007/s40299-019-00486-w

*Chen, J. C. (2022). Developing a cycle-mode POED model and using scientific inquiry for a practice activity to improve students' learning motivation, learning performance, and hands-on ability. *Interactive Learning Environments, 30*(7), 1252-1264. https://doi.org/10.1080/10494820.2020.1716023

*Chen, Y. L., Pan, P. R., Sung, Y. T., & Chang, K. E. (2013). Correcting misconceptions on electronics: Effects of a simulation based learning environment backed by a conceptual change model. *Educational Technology & Society, 16*(2), 212-227.

Coe, C. W. M. (1993). *Predict-observe-explain science activities in the junior high classroom: A qualitative inquiry* [Master's thesis, St. Mary's University]. ProQuest Dissertations & Theses Global.

Cohen, L., Manion, L., & Morrison, K. (2002). *Research methods in education*. Routledge. https://doi.org/10.4324/9780203224342

Cooper, H., Hedges. L. V., & Valentine, J. C. (Eds.). (2009). *The handbook of research synthesis and meta-analysis* (2nd ed.). Russell Sage Publication.

*Coştu, B. (2008). Learning science through the pdeode teaching strategy: Helping students make sense of everyday situations. *Eurasia Journal of Mathematics, Science & Technology Education, 4*(1), 3-9. https://doi.org/10.12973/ejmste/75300

*Coştu, F. (2021). *Investigation of the predict-explain-obseve discuss-explain based laboratory activities on pre-service science teachers' achievement, conceptual understanding and science process skills* [Doctoral dissertation, Marmara University]. Council of Higher Education Thesis Center.

*Çalış, S., & Özkan, M. (2022). The effect of science teaching based on POE strategy on the academic achievement and attitudes of fifth-grade students in the distance education process. *Mimbar Sekolah Dasar, 9*(3), 381-395. https://doi.org/10.53400/mimbarsd.v9i3.45472

*Çıngıl Barış, Ç. (2022). The effect of the 'predict-observe-explain (POE)' strategy in teaching photosynthesis and respiration concepts to pre-service science teachers. *Journal of Biological Education.* https://doi.org/10.1080/00219266.2022.2047097

*Çinici, A., Sözbilir, M., & Demir, Y. (2011). Effect of cooperative and individual learning activities on students' understanding of diffusion and osmosis. *Eurasian Journal of Educational Research*, 43, 19-36.

Delen, I., & Şen, S. (2023). Effect of design-based learning on achievement in K-12 education: A meta-analysis. *Journal of Research in Science Teaching*, *60*(2), 330-356. https://doi.org/10.1002/tea.21800

Dickersin, K. (2005). Publication bias: Recognizing the problem, understanding its origins and scope, and preventing harm. In H. R. Rothstein, A. J. Sutton, & M. Borenstein (Eds.), *Publication bias in meta-analysis: Prevention, assessment and adjustments* (pp.11-33). John Wiley & Sons.

Duval, S., & Tweedie, R. (2000). Trim and fill: A simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics, 56*(2), 455-463. https://doi.org/10. 1111/j.0006-341X.2000.00455.x

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ, 315,* 629-634. https://doi.org/10.1136/bmj.315.7109.629

*Erdem Özcan, G., & Uyanık, G. (2022). The effects of the "predict-observe-explain (POE)" strategy on academic achievement, attitude and retention in science learning. *Journal of Pedagogical Research, 6*(3), 103-111. https://doi.org/10.33902/JPR.202215535

Evangelou, F., & Kotsis, K. (2019). Real vs virtual physics experiments: comparison of learning outcomes among fifth grade primary school students. A case on the concept of frictional force. *International Journal of Science Education, 41*(3), 330-348, https://doi.org/10.1080/09500693.2018.1549760

*Fateen, R. (2020). *Comparing inquiry-based teaching strategies for improving and implementing computer simulation-based instruction of science concepts* [Doctoral dissertation, Southern Illinois University]. ProQuest Dissertations & Theses Global.

Field, A. P., & Gillett, R. (2010). How to do a meta-analysis. *The British Journal of Mathematical and Statistical Psychology, 63*(3), 665-694. https://doi.org/10.1348/000711010X502733

*Furqani, D., Feranie, S., & Winarno, N. (2018). The effect of predict-observe-explain (POE) strategy on students' conceptual mastery and critical thinking in learning vibration and wave. *Journal of Science Learning, 2*(1), 1-8. https://doi.org/10.17509/jsl.v2i1.12879

George, D., & Mallery, M. (2010). *SPSS for windows step by step: A simple guide and reference, 17.0 update* (10th ed.). Pearson.

Glass, G. V., Smith, M. L., & McGaw, B. (1981). *Meta-analysis in social research*. Sage.

Guerrero, T.A., Griffin, T.D. & Wiley, J. (2022). I think i was wrong: The effect of making experimental predictions when learning about theories from psychology textbook excerpts. *Metacognition Learning 17,* 337-373. https://doi.org/10.1007/s11409-021-09276-6

Gunstone, R. F., & White, R. T. (1981). Understanding of gravity. *Science Education, 65*(3), 291 299. https://doi.org/10.1002/sce.3730650308

Gustina, R., Hastuti, I. D., Nizaar, M., & Syaharuddin, S. (2023). Predict observe explain learning model: Implementation and its influence on students' critical thinking ability and learning outcomes (a meta-analysis study). *Jurnal Kependidikan: Jurnal Hasil Penelitian dan*

Kajian Kepustakaan di Bidang Pendidikan, Pengajaran dan Pembelajaran, 9(2), 706-718. https://doi.org/10.33394/jk.v9i2.7388

*Harman, G., & Yenikalayci, N. (2022). The effect of prediction-observation-explanation (POE) method on learning of image formation by a plane mirror and pre-service teachers' opinions. *Journal of Educational Research and Practice, 12*(1), 1-17. https://doi.org/10.5590/JERAP.2022.12.1.1

Hedges, L. V. (1982). Fitting categorical models to effect sizes from a series of experiments. *Journal of Educational Statistics, 7*(2), 119-137. https://doi.org/10.2307/1164961

Hedges, L. V., & Olkin, I. (1985). *Statistical model of meta-analysis*. Academic Press.

Higgins, J. P., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analysis. *British Medical Journal, 327*(7414), 557-560. https://doi.org/10.1136/bmj.327.7414.557

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundation for the 21st century. *Science Education, 88*(1), 28-54. https://doi.org/10.1002/sce.10106

*Hsiao, H. S., Chen, J., Hong, J. C., Chen, P. H., Lu, C. C., & Chen, S. Y. (2017). A five-stage prediction-observation-explanation inquiry-based learning model to improve students' learning performance in science courses. *Eurasia Journal of Mathematics, Science and Technology Education, 13*(7), 3393-3416. https://doi.org/10.12973/eurasia.2017.00735a

*Hsu, C. Y., Tsai, C. C., & Liang, J. C. (2011). Facilitating preschoolers' scientific knowledge construction via computer games regarding light and shadow: The effect of the prediction observation-explanation (POE) strategy. *Journal of Science Education Technology, 20*(5), 482-493. https://doi.org/10.1007/s10956-011-9298-z

Huedo-Medina, T. B., Sánchez-Meca, J., Marín-Martínez, F., & Botella, J. (2006). Assessing heterogeneity in meta-analysis: Q statistic or I^2 index? *Psychological Methods, 11*(2), 193 206. https://doi.org/10.1037/1082-989X.11.2.193

IBM Corp. (2019). *IBM SPSS statistics for windows* (Version 26.0) [Computer software]. IBM Corp.

*James, N. M., Kreager, B. Z., & LaDue, N. D. (2022) Predict-observe-explain activities preserve introductory geology students' self-efficacy. *Journal of Geoscience Education, 70*(2), 238-249. https://doi.org/10.1080/10899995.2021.1906593

*Kahraman, S. (2023). The use of dynamic computer visualizations integrated with the poe sequence: Its effect on learners' understanding, retention, and motivation. *Canadian Journal of Science, Mathematics and Technology Education, 23,* 179-209. https://doi.org/10.1007/s42330-023-00284-z

*Karamustafaoğlu, S., & Mamlok-Naaman, R. (2015). Understanding electrochemistry concepts using the predict-observe-explain strategy. *Eurasia Journal of Mathematics, Science and Technology Education, 11*(5), 923-936. https://doi.org/10.12973/eurasia.2015.1364a

*Karpin, T., Juuti, K., & Lavonen, J. (2014) Learning to apply models of materials while explaining their properties. *Research in Science & Technological Education, 32*(3), 340-351. https://doi.org/10.1080/02635143.2014.944494

*Karslı Baydere, F. (2021). Effects of a context-based approach with prediction-observation explanation on conceptual understanding of the states of matter, heat and temperature. *Chemistry Education Research and Practice, 22*(3), 640-652. https://doi.org/10.1039/d0rp00348d

Kearney, M. (2002). *Classroom use of multimedia-supported predict-observe-explain tasks to elicit and promote discussion about students' physics concepts* [Unpublished doctoral dissertation]. Curtin University of Technology.

Kearney, M. (2004). Classroom use of multimedia-supported predict observe-explain tasks in a social constructivist learning environment. *Research in Science Education, 34*(4), 427-453. https://doi.org/10.1007/s11165-004-8795-y

*Kibirige, I., Osodo, J., & Tlala, K. M. (2014). The effect of predict-observe-explain strategy on learners' misconceptions about dissolved salts. *Mediterranean Journal of Social Sciences, 5*(4), 300-310. https://doi.org/10.5901/mjss.2014.v5n4p300

Konstantopoulos, S., & Hedges, L. V. (2009). Analyzing effect sizes: Fixed-effects models. In H. Cooper, L. V. Hedges, & J. C. Valentine (Eds.)., *The hand. of research synthesis and meta analysis, 2nd ed.* (pp. 279-293). Russell Sage Foundation.

Li, Y. D., Ding, G. H., & Zhang, C. Y. (2021). Effects of learner-centred education on academic achievement: A meta-analysis. *Educational Studies*. https://doi.org/10.1080/03055698.2021.1940874

Liew, C. W., & Treagust, D. F. (1998). *The effectiveness of predict-observe explain tasks in diagnosing students' understanding of science and in identifying their levels of achievement* (ED420715). ERIC. https://files.eric.ed.gov/fulltext/ED420715.pdf

Lipsey, M. W., & Wilson, D. B. (2001). *Practical meta-analysis*. SAGE Publications.

*Lucas, L., Helikar, T., & Dauer, J. (2022) Revision as an essential step in modeling to support predicting, observing, and explaining cellular respiration system dynamics. *International Journal of Science Education, 44*(13), 2152-2179. https://doi.org/10.1080/09500693.2022.2114815

Matthews, M. R. (2002). Constructivism and science education: a further appraisal. *Journal of Science Education and Technology, 11*(2), 121-134.

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Prisma Group. (2009). Reprint-preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Physical Therapy, 89*(9), 873-880. https://doi.org/10.1093/ptj/89.9.873

Mutlu, A., & Acar Şeşen, B. (2016). Predict-observe-explain tasks in chemistry laboratory: Pre service elementary teachers' understanding and attitudes. *Sakarya University Journal of Education, 6*(2), 184-208. http://dx.doi.org/10.19126/suje.46187

Nurshafara, A. (2022). *Meta-analysis of the effect of the predict observe explain (POE) leaming model on students' physics leaming outcomes* [Unpublished skripsi thesis]. Universitas Negeri Padang.

*Nyirahabimana, P., Minani, E., Nduwingoma, M., & Kemeza, I. (2023). Multimedia-aided technologies for effective learning of quantum physics at the university level. *Journal of Science Education and Technology, 32,* 686-696. https://doi.org/10.1007/s10956-02310064-x

*Özçelik, H. (2019). *Examining the effect of predict-observe-explain (poe) method supported with concept cartoons on secondary school students' inquiry skills, science process skills and conceptual understanding* [Master's thesis, Marmara University]. Council of Higher Education Thesis Center.

*Özkan, M. (2022). *The effect of science teaching based on poe straregy on the academic achievement and attitudes of secondary school students in the distance education process* [Master's thesis, Bursa Uludağ University]. Council of Higher Education Thesis Center.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Systematic Reviews, 10*(1), 1-11. https://doi.org/10.1186/s13643-02001552-x

Palmer, D. (1995). The POE in the primary school: An evaluation. *Research in Science Education, 25*, 323-332. https://doi.org/10.1007/BF02357405

Rodriguez, J. E., Williams, D. R., & Bürkner, P. C. (2023). Heterogeneous heterogeneity by default: Testing categorical moderators in mixed-effects meta-analysis. *The British Journal of Mathematical and Statistical Psychology, 76*(2), 402-433. https://doi.org/10.1111/bmsp.12299

Rosenthal, R. (1991). *Meta-analytic procedures for social research*. Sage Publications.

Ross, B., & Munby, H. (1991). Concept mapping and misconceptions: A study of high-school students' understandings of acids and bases. *International Journal of Science Education, 13*(1), 11-23. https://doi.org/10.1080/0950069910130102

Sarkis-Onofre, R., Catalá-López, F., Aromataris, E., & Lockwood, C. (2021). How to properly use the PRISMA Statement. *Systematic Reviews, 10*(1), 1-3. https://doi.org/10.1186/s1364302101671-z

Tao, P. K., & Gunstone, R. F. (1997). *The process of conceptual change in 'force and motion'* (ED407259). ERIC. https://files.eric.ed.gov/fulltext/ED407259.pdf

*Tetik, S. (2019). *The effect of teaching the topic of liquids in 9. grade chemistry course with the 5E model and the tga technique (prediction-observation-explanation) on the success of students* [Master's thesis, Marmara University]. Council of Higher Education Thesis Center.

Thalheimer, W., & Cook, S. (2002). How to calculate effect sizes from published research: A simplified methodology. *Work-Learning Research, 1,* 1-9.

*Tokay, E. (2022). *The effect of the prediction-observation-explanation (POE) method on the students' academic achievement and motivation in the subject of 'Acids and bases' in the 10th grade chemistry course* [Master's thesis, Dokuz Eylül University]. Council of Higher Education Thesis Center.

Tüysüz, A., & Özdemir, Ö. F. (2024). An experimental study exploring the effects of predict observe-explain method supported with simulations. *Research in Science & Technological Education*. https://doi.org/10.1080/02635143.2023.2296458

UNESCO. (2012). *International standard classification of education: ISCED 2011*. UNESCO Institute for Statistics. https://doi.org/10.1108/S0195-6310(2013)0000030017

Vevea, J. L., Coburn, K., & Sutton, A. (2019). Publication bias. In H. Cooper, L. V. Hedges, & J. C. Valentine (Eds.), *The handbook of research synthesis and meta-analysis* (3rd ed., pp. 383-430). Russell Sage Foundation.

White, R., & Gunstone, R. (1992). *Probing understanding.* The Falmer Press.

White, R. T. (1988). *Learning science.* Basil Blackwell.

White, W. A. T. (1988). A meta-analysis of the effects of direct instruction in special education. *Education and Treatment of Children, 11*(4), 364-374. https://www.jstor.org/stable/42899084

*Wiyarsi A., Prodjosantoso, A. K., & Nugraheni, A. R. E. (2021). Promoting students' scientific habits of mind and chemical literacy using the context of socio-scientific issues on the inquiry learning. *Frontiers in Education, 6,* 1-12. https://doi.org/10.3389/feduc.2021.660495

*Yaman, F., & Ayas, A. (2015). Assessing changes in high school students' conceptual understanding through concept maps before and after the computer-based predict-observe explain (CB-POE) tasks on acid-base chemistry at the secondary level. *Chemistry Education Research and Practice, 16*(4), 843-855. https://doi.org/10.1039/C5RP00088B

Yaman, F., Ayas, A., & Çalık, M. (2019). Facilitating grade 11 students' conceptual understanding of fundamental acid-base models. *Turkish Journal of Education, 8*(1), 16-32. https://doi.org/10.19128/turje.449100

Yang, K. H., & Chen, H. H. (2023) What increases learning retention: Employing the prediction observation-explanation learning strategy in digital game-based learning. *Interactive Learning Environments, 31*(6), 3898-3913. https://doi.org/10.1080/10494820.2021.1944219

Zacharia, Z. C., Olympiou, G., & Papaevripidou, M. (2008). Effects of experimenting with physical and virtual manipulatives on students' conceptual understanding in heat and temperature. *Journal of Research in Science Teaching, 45*(9), 1021-1035. https://doi.org/10.1002/tea.20260

*Zhao, L., He, W., Liu, X., Tai, K. H., & Hong, J. C. (2021). Exploring the effects on fifth graders' concept achievement and scientific epistemological beliefs: Applying the prediction observation-explanation inquiry-based learning model in science education. *Journal of Baltic Science Education, 20*(4), 664-676. https://doi.org/10.33225/jbse/21.20.664

Geniş Özet

Problem Durumu

Fen eğitiminde klasik yaklaşımdan yapılandırmacı yaklaşıma geçişle birlikte öğrenci merkezli öğretim yöntem ve teknikleri ön plana çıkmıştır. Araştırma-sorgulamaya dayalı öğrenme çatısı altında yer alan, sosyal yapılandırmacılık ile uyumlu olan, öğrencilerin kendi öğrenmelerinden sorumlu olduğu tahmin gözlem açıklama (TGA) öğrenci merkezli stratejilerden biridir. Klasik araştırma basamaklarına dayanan TGA hipotez oluşturma, hipotezin gerekçelerini ifade etme, hipotezi test etmek için veri toplama ve sonuçları tartışma adımlarını içermektedir (Kearney, 2004; White, 1988). TGA'da öğrenciler gerçekleştirilecek bir deney veya etkinlik öncesinde gerekçeli tahminde bulunurlar, daha sonra deney veya etkinlikle ilgili gözlem yaparlar. Son olarak tahmin ve gözlemleri arasında bir fark olup olmadığını açıklarlar (White, 1988; White & Gunstone, 1992).

TGA, uzun süredir fen eğitiminde kullanılmaktadır (Gunstone & White, 1981; White & Gunstone, 1992). TGA stratejisinin fen başarısına etkisini konu alan pek çok deneysel araştırma yapılmıştır. Bu deneysel araştırma sonuçlarının birleştirilerek bir meta-analiz çalışmasının yapılması genel sonucu görmeye yardımcı olacaktır. Literatürde TGA stratejisi ile ilgili şu ana kadar yapılan iki adet meta-analiz çalışmasına rastlanmıştır (Gustina vd., 2023; Nurshafara, 2022). Mevcut meta-analiz çalışmalarından farklı olarak, özellikle fen kavramların yapılandırıldığı deneylerde kullanılan TGA stratejisinin, fen başarısı üzerinde ne kadar etkili olduğunun belirlenmesi; bilim alanı, uygulanma şekli, öğretim kademesi, uygulama süresi ve yayın yılı gibi farklı moderatörlerin hesaba katılarak analiz yapılması önem teşkil etmektedir. Bu doğrultuda bu meta-analiz çalışmasında aşağıdaki problemlere yanıt aranmıştır:

(1) TGA stratejisinin öğrencilerin fen başarısı üzerindeki etkisi nedir?

(2) TGA stratejisinin öğrencilerin fen başarısı üzerindeki etkisi bilim alanına, uygulanma şekline ve öğretim kademesine göre anlamlı farklılık göstermekte midir?

(3) Uygulama süresi ve yayın yılı, TGA stratejisinin öğrenci fen başarısı üzerindeki etkisinin anlamlı bir yordayıcısı mıdır?

Yöntem

Bu araştırmada, TGA stratejisinin öğrencilerin fen başarısı üzerindeki etkisi meta-analiz yöntemiyle incelenmiştir. Çalışmaların seçimi ve analizinde Card (2012), Field ve Gillett (2010), Glass vd. (1981) tarafından önerilen 3 aşamalı prosedür izlenmiştir: (1) Çalışmaların seçimi, (2) kodlama stratejisi, (3) veri analizi.

Taramalar "predict", "observe" ve "explain" anahtar kelimeleri kullanılarak gerçekleştirilmiştir. Makalelerin taranmasında eğitimle ilgili kaliteli ve popüler bazı dergileri kapsadıkları için "Web of Science (WoS)", "Scopus" ve "Education Resources Information Center (ERIC)" veri tabanları; tezlerin taranmasında "ProQuest Dissertations & Theses Global (PQDT)" veri tabanı tercih edilmiştir. Meta-analize dahil edilen çalışmaların belirlenmesinde uygulanan kriterler şunlardır: (1) TGA ve fen başarısı ile ilgili çalışmalar, (2) 2003-2023 yılları arasında yayımlanmış erişime açık tam metinli çalışmalar, (3) İngilizce veya Türkçe yayımlanmış çalışmalar, (4) çalışmaların tez veya hakemli dergilerde makale türünde yayımlanması, (5) çalışmaların TGA uygulaması içermesi, (6) çalışmaların, etki büyüklüğünün hesaplanması için yeterli veriye sahip olması. Bu kriterlere uygun olarak meta-analize PQDT'den 6, WoS'tan 6, Scopus'tan 18 ve ERIC'ten 5 olmak üzere toplam 35 çalışma dahil edilmiştir. Bu çalışmalardan 39 bağımsız etki büyüklüğü değeri elde edilmiştir. Yayın yanlılığı kontrolü, etki büyüklüğü değerlerinin hesaplanması, heterojenlik testi ve moderatör analizlerinin tamamında Comprehensive Meta-Analysis (CMA) programının ücretsiz deneme sürümü kullanılmıştır.

Bulgular

Analiz sonuçları, TGA stratejisinin öğrencilerin fen başarısı üzerinde yüksek düzey etkiye sahip olduğunu ortaya koymuştur. Bilim alanı moderatörüne göre TGA stratejisi öğrencilerin fen başarısını anlamlı olarak farklılaştırmıştır. Ortalama etki büyüklüğü değerleri astronomi, biyoloji, kimya, kimya-fizik, yerbilimi ve fizik bilim alanları için sırasıyla 0.760, 0.825, 1.327, 2.398, 0.215 ve 0.815'tir. TGA stratejisi yerbilimi bilim alanında öğrencilerinin fen başarısını Thalheimer ve Cook'un (2002) sınıflamasına göre düşük düzeyde; astronomi, biyoloji ve fizik alanlarında yüksek düzeyde, kimya alanında çok yüksek düzeyde, kimya-fizik alanında mükemmel düzeyde etkilemiştir. TGA'nın tek başına ve teknoloji ile desteklenerek uygulanma şeklinin öğrencilerin fen başarısını benzer ve yüksek düzeyde etkilediği söylenebilir. Ortalama etki büyüklüğü değerleri TGA ve teknoloji destekli TGA için sırasıyla 1.019 ve 0.875'tir. Öğretim kademesi moderatörüne göre TGA stratejisi öğrencilerin fen başarısını anlamlı olarak farklılaştırmıştır. Ortalama etki büyüklüğü değerleri lise, ortaokul, okul öncesi, ilkokul ve üniversite için sırasıyla 1.229, 0.515, 0.494, 1.015 ve 1.100'dür. TGA stratejisi lise ve üniversite öğretim kademesinde öğrencilerin fen başarısını çok yüksek düzeyde, ilkokulda yüksek düzeyde, ortaokul ve okul öncesi kademelerinde orta düzeyde etkilemiştir. Meta-regresyon analizleri uygulama süresi ve yayın yılının, TGA stratejisinin öğrenci fen başarısı üzerindeki etkisinin anlamlı birer yordayıcısı olmadığını göstermiştir ($p>0.05$).

Sonuç ve Tartışma

Araştırma sonucunda TGA stratejisinin öğrencilerin fen başarısı üzerinde yüksek düzeyde bir etkiye sahip olduğu görülmüştür. Bu bulgu TGA stratejisinin öğrenme çıktıları üzerindeki etkisini inceleyen önceki meta-analiz çalışmaları ile uyumludur (Gustina vd., 2023; Nurshafara, 2022). Bilim alanı moderatörüne göre TGA stratejisi öğrencilerin fen başarısını anlamlı olarak farklılaştırmıştır. Fizik, kimya ve biyoloji alanlarında gerçekleştirilen etkinlik ve deneylerin kısa sürede yapılabilmesi, tekrar edilebilir olması TGA stratejisini öğrenci başarısını artırmada daha etkili kılmış olabilir. Yerbilimi alanında yapılan deney ve etkinlikler genelde gözlem ve incelemeye dayalıdır. Dolayısıyla yerbilimi alanında yapılan deney ve etkinlik sürecinde öğrencilerin daha az aktif olacağı düşüncesinden yola çıkarak, yerbilimi alanında TGA stratejisinin uygulanmasının öğrenci başarısını artırmada daha az etkili olduğu iddia edilebilir. Araştırma sonucunda TGA ve teknoloji destekli TGA'nın öğrencilerin fen başarısını yüksek ve benzer düzeyde etkilediği görülmüştür. Buradan TGA'nın öğrencilerin fen başarısını etkilemede teknoloji ile desteklenmeden tek başına uygulanmasının da etkili olduğu iddia edilebilir. Bu meta-analiz çalışmasında TGA stratejisinin ilkokul kademesinde uygulanmasının yüksek düzeyde etkili olduğu görülmüştür. Erdem ve Özcan Uyanık (2022), TGA'nın ilkokul kademesinde uygulanmasının

Van Yüzüncü Yıl University Journal of Education, 2024; 21(3), p. 893-920. DOI: 10.33711/yyuefd.1570041

eğlenceli ve merak uyandırıcı olduğunu, kalıcı öğrenmeyi sağladığını ifade etmişlerdir. İlkokul kademesindeki öğrenciler sözlü iletişim kurarak düşüncelerini açıklama eğiliminde oldukları için Palmer (1995) TGA stratejisinin ortaokul ve lise kademelerinde uygulanmasından ziyade ilkokul kademesinde uygulanmasının daha etkili olduğunu öne sürmüştür. Ayrıca, TGA stratejisinin öğrenci fen başarısı üzerindeki etkisinin uygulama süresi ve yayın yılı değişkenlerinden etkilenmediği görülmüştür. Meta-analize dahil edilen çalışmaların son yıllarda yoğunlaştığı görülmekle birlikte yayın yılları 2008-2023 arasında değişmektedir. Çalışmaların uygulama süresi 1-12 hafta arasında değişmekle birlikte ortalaması 4.8 haftadır.

