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A REVIEW OF STUDIES CONDUCTED WITH THE PREDICTION-OBSERVATION-EXPLANATION (POE) IN BIOLOGY EDUCATION

(Research article)

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Abstract

The aim of the research is to provide a general framework for POE used in biology education using meta-synthesis. In this research; studies on the use of the prediction-observation-explanation (POE) in biology education between the years 2000-2020 in Turkey and the World have been examined considering research type, distribution of the studies by years, the preferred research groups, the research methods used, the data collection tools used and the subject areas. The researches included in the research were obtained in Turkish and English by systematically scanning the literature covering the years 2000-2020 from the Google search engine, Web of Science, ERIC database, Google Academic Search, The Scientific and Technological Research Council of Turkey (ULAKBİM) database, ProQuest dissertation database and Higher Education Council's (HEC) National dissertation center. 27 studies were reached within the framework of inclusion criteria. It has been determined that the studies are distributed as 21 article, 5 master thesis and 1 doctoral dissertation according to the research type. Obtained data were interpreted on the basis of the frequency and were sometimes indicated with tables and graphs. According to the consequences; it was stated that most of the studies were in the type of research, pre-service teachers were preferred more than other samples, quantitative studies were more than qualitative studies, academic achievement tests were used the most as data collection tool and "Diffusion-Osmosis" subjects was studied the most.

Keywords: Predict-observe-explain, POE, biology education, science education, literature

1. Introduction

1.1. Literature Review

Education is the enrichment of human knowledge and experience by going through the process of experimental thinking and inference. Learning is meaningful when an individual can construct and transfer knowledge in their own way, and use it in new learning situations. Teaching science concepts to 21st century learners, known as "born researchers" has become more difficult than ever in the past decade. Students today do not like the learning situation where teachers are the only source of information in the classroom and they become passive receivers of information. Instead, they learn best in active learning environments that increase their curiosity, enable them to apply different process skills and build conceptual understanding on their own (Sezgin-Selçuk, Çalışkan, & Şahin 2013; Zion & Mendelovici, 2012). This changing nature of 21st century learners has prompted many countries to initiate a major curriculum reform to keep abreast of changing trends in education and provide students with the most appropriate education (Sarvi, Munger & Pillay, 2015). This current problem requires another method that will also increase the curiosity of 21st century learners. The Predict-Observe-Explain (POE) (Hilario, 2015), which emphasizes the use of students' scientific process skills and pre-existing knowledge in constructing new knowledge, is easy to apply for both learners and teachers (Nurhuda, Lukito & Masriyah, 2018). POE is a student-centered,

applied strategy developed by White & Gunstone in 1992, emphasizing the use of students' scientific skills, especially in predicting, observing, and explaining, in forming a conceptual understanding of a particular topic (Yuenyong & Thathong, 2015).

The constructivist learning approach differs from the traditional learning approach, which accepts that knowledge is objective, with the argument that the knowledge is subjective and is actively created by the learner (Erdamar-Koç & Demirel, 2008). Constructivism is a learning theory that has been nurtured by philosophy and psychology and dates back to ancient times (Bay, 2008). When the constructivist approach emerged, it was adopted as a teaching approach, and in the following years it was distanced from this approach in terms of philosophical understanding and transformed into a learning approach. The constructivist learning approach emphasizes that the old information is activated for the new information to be obtained in accessing the information, the information that is in harmony with the old information is especially selected and the new information obtained is effectively structured in the mind of the individual. Various learning models (Learning cycle, 4E, 5E and 7E models) and teaching methods and strategies (POE, Analogy) can be given as examples for the application of the constructivist approach, which defends that learners learn by associating new knowledge with their prior knowledge (Ayas, 1995; Çalık, 2006; Köseoğlu, Tümay & Kavak, 2002; Şahin, 2010). POE is a technique that requires learners to predict an event or the outcome of a situation in an activity, write down their predictions with their justifications, observe the event and explain whether there is a difference between their predictions and observations, so that information is reconstructed in their minds (White & Gunstone, 1992; Kearney & Treagust, 2001). With the POE, which is one of the techniques based on the constructivist approach, students are given the opportunity to apply what they have learned in activities to be carried out in the laboratory or outside, and the opportunity to associate science knowledge with natural events in daily life is provided (White & Gunstone, 1992). Effective acquisition of knowledge and skills related to science is closely linked to the quality of conceptual teaching to be applied in science lessons (Ateş & Bahar, 2002). The POE used to reveal students' knowledge on a particular subject and to provide conceptual change in teaching was developed by White & Gunstone (1992).

With the POE, students encounter real problem situations, not problem situations presented theoretically. In this way, students actively participate in the solution of the problem situation (White & Gunstone, 1992). POE-based learning provides students with the opportunity to use their scientific process skills and make them feel like a scientist using scientific methods. This method, which enables them to link their previous knowledge with the new information they have learned and to express their knowledge in a meaningful way, is very suitable for science lessons. It allows students to take responsibility, express themselves and improve their self-confidence in their own or group work. In addition, learners are constantly active in the process, being responsible for their own learning, and applying what they learn to daily life help them develop positive attitudes towards science lessons (Bilen, 2009). POE technique consists of three stages. These stages are:

1.1.1. Prediction Stage

In the first stage, the prediction stage, students are given information about an event or an experiment, and they are asked to predict the results and write down the reasons. Starting the prediction stage with a sample event is also important in terms of arousing curiosity and interest in the student (Sarı & Şengül, 2018). In such applications, multiple choice or open-ended questions can be asked to students. At this stage, students can provide justifications to confirm their predictions, regardless of whether they have made a correct prediction about a concept that is mentioned in the show or situation they are examining. The reasons students give to

their predictions are important in terms of revealing their prior knowledge about the event and their misconceptions, if any (Driver, 1983; Searle, 1995). In addition, predicting increases students' motivation by concentrating on the event under investigation. It develops students' ability to choose among the ideas and beliefs they have, and to make decisions (Gunstone, 1995).

1.1.2. Observation Stage

The second stage is the observation stage. During the observation stage, the demonstration experiment that students predicted is performed or they are made observations by watching videos. At this stage, students are provided to record their observation results on their worksheets. At this stage, students should make their own observations on the predicted situation and the event to be observed should be understandable and observable by the student (Tao & Gunstone, 1997).

1.1.3. Explanation Stage

The third stage is the explanation stage. At this stage, where students construct their knowledge by comparing their predictions and observations, students are asked to determine the harmony or contradiction between their predictions and observations, to determine their reasons, and to resolve the contradiction (White & Gunstone, 1992). Since it is important for students to develop alternative ideas that explain their thoughts and to reconstruct their concepts at this stage, the teacher should encourage and guide the students when they have difficulty (Atasoy, 2002).

1.2. The Importance of Research

This research; POE conducted studies in biology education in Turkey and in the world in terms of a detailed explanation will shed light on researchers to conduct research in this area. By reading this article instead of reading 27 studies one by one, researchers will be able to understand how POE is used in biology education in general and direct their own studies in a better way. In addition, thanks to this article, which reveals explanatory information about the development, efficiency and applicability of the studies, the researchers will be able to see which subjects have been studied before, so that the same type of studies can be prevented.

1.3. Aim of the Research

In this research, studies on the POE used in biology education were studied in terms of different criteria. It is thought that the data obtained are important in terms of revealing the trend towards the POE. In line with this aim, responses to the following problems were sought:

1. What is the research type of the studies examined?

2. What is the distribution of the examined studies by years?

3. Which are the preferred research groups in the studies examined?

4. What are the research methods used in the studies examined?

5. What are the data collection tools used in the studies examined?

6. In which subject areas were the studies examined?

2. Methodology

2.1. Research Design

Meta synthesis, which is a qualitative study design, was used in this study. Meta synthesis is a method that research studies and investigates the results of various studies and tries to interpret the data obtained as a result of this research (Finfgeld, 2003). With meta synthesis

research, it is aimed to examine studies conducted in a certain field with a qualitative understanding, to reveal their similarities and differences in a comparative manner, and to create a rich reference resource for researchers, teachers and other relevant people who have no access to all studies (Çalık & Sözbilir, 2014). In this study, a meta synthesis design was used to analyze the studies about POE in biology education and to determine what a trend it is.

2.2. Data Collection

The sample of this research consists of 27 studies on POE used in biology education, which were reached as a result of a literature review. A purposeful sampling method was used in this study. Purposeful sampling allows in depth analysis of situations that can best represent the population and offer rich data (Büyüköztürk, Çakmak, Akgün, Karadeniz & Demirel, 2008). Document analysis is used as a data collection method in the research. The researches included in the research were obtained in Turkish and English by systematically scanning the literature covering the years 2000-2020 from the Google search engine, Web of Science, ERIC database, Google Academic Search, The Scientific and Technological Research Council of Turkey (ULAKBİM) database, ProQuest dissertation database and Higher Education Council's (HEC) national dissertation center. Some criteria were determined for the studies obtained to be included in the study. These:

1. It contains the keywords "prediction-observation-explanation" and "POE",
2. Being scanned in databases,
3. The research field should be "biology education",
4. Date range is between 2000-2020,
5. The language of the publication should be English or Turkish,
6. The type of publication is an article or a thesis,
7. Having open access,
8. No screening study.

Studies made using the POE in Turkey and the World constituted the universe of the research. Considering the actuality principle, the workable universe has covered the last 20 years (2000-2020). As a consequence of the literature review, 21 articles and 6 theses related to the POE used in biology education were determined and included in the research.

2.3. Coding Method

Under the light of information obtained from studies and theses, the themes were investigated according to qualitative and quantitative findings and codes were formed in order to provide easy interpretations from analyses (Table 1). Studies taken into the scope of this study was sorted according to features and their publication years and coded as "X_1, X_2, ..., X_{27}" for convenience. Interpretations and analyses were made according to this coding (Table 2).

Table 1. *Codes of meta synthesis*

Themes	Theme Contents
Academic Achievement	AA-POE's Effect on Academic Achievement
Attitude	A-POE's Effect on Attitude
Scientific Process Skills	SPS-POE's Effect on Scientific Process Skills
Critical Thinking	CT-POE's Effect on Critical Thinking
Misconception	M- POE's Effect on Misconception
The Nature of Science	NS-POE's Effect on the Nature of Science
Views	V-Views with regard to POE

Table 2. *The studies found as a result of literature review and their codes*

Code	Author(s)	Year	Type of Publication	Research Model	Theme
X_1	Köse, Coştu, & Keser	2003	Article	Qualitative	V
X_2	Wu & Tsai	2005	Article	Quantitative	V
X_3	Demirelli,, Özkaya, Demir, Altınkaynak, Akgül, & Başkurt	2008	Article	Quantitative	AA, A
X_4	McGregor, & Hargrave	2008	Article	Quantitative	AA
X_5	Bilen	2009	Thesis (MSc)	Quantitative	AA, A, SPS, NS
X_6	Özyılmaz-Akamca, & Hamurcu	2009	Article	Quantitative	AA, A
X_7	Bilen, & Aydoğdu	2010	Article	Quantitative	AA, A
X_8	Çinici, & Demir	2010	Article	Quantitative	A
X_9	Bilen, Köse, & Uşak	2011	Article	Quantitative	AA
X_{10}	Çinici, Sözbilir, & Demir	2011	Article	Quantitative	AA, A, SPS
X_{11}	Tokur	2011	Thesis (MSc)	Quantitative	AA, A, SPS
X_{12}	Bilen, & Köse	2012a	Article	Mixed	AA
X_{13}	Bilen, & Köse	2012b	Article	Quantitative	AA, A
X_{14}	Karatekin, & Öztürk	2012	Article	Quantitative	AA, SPS
X_{15}	Çetin	2013	Thesis (MSc)	Quantitative	AA
X_{16}	Güven	2014	Article	Mixed	A, V
X_{17}	Harman	2014	Article	Qualitative	M
X_{18}	Göktürk	2015	Thesis (MSc)	Mixed	AA, A, V
X_{19}	Bilen, Özel, & Köse	2016	Article	Qualitative	V
X_{20}	Güngör	2016	Thesis (PhD)	Mixed	AA, SPS, V
X_{21}	Kozcu-Çakır, Güven, & Özdemir	2017	Article	Mixed	AA, SPS, V
X_{22}	Güngör, & Özkan	2017	Article	Qualitative	V
X_{23}	Widiyaningrum, Bintari, & Rahayuningsih	2018	Article	Mixed	AA, A
X_{24}	Fitriani, Zubaidah, Susilo, & Al Muhdhar	2020	Article	Quantitative	A, CT
X_{25}	Güleşir, Aydemir, Kuş, Uzel, & Gül	2020	Article	Qualitative	V
X_{26}	Kasım	2020	Thesis (PhD)	Mixed	AA, V
X_{27}	Prabawati, Nugrahaningsih, & Alimah	2020	Article	Quantitative	AA

2.4. Data Analysis

In this research, the studies examined are presented in tables or graphs in accordance with the purpose of the themes. The purpose of presenting the data in this way is to be both visual and to have an idea about the studies carried out at first glance. A total of 27 studies, which were reached as a consequence of the literature review and were suitable to be included in the research, were analyzed considering the criteria determined in seeking answers to research

problems. Each study has been evaluated in detail within the framework of research problems. In this framework, the characteristics of the research group, research method, data collection tools and subject area of researches were examined in detail. The frequency (f) and percentage (%) values for the results are presented in the results section.

2.5. Validity and Reliability

In order to avoid any mistakes during coding, the studies were examined for a long time and all the summary information obtained was written down. Approximately one month later, the researcher repeated the analysis in order for the coding to be reliable. In addition, to ensure the reliability of the data analysis, the articles were coded separately by two science education experts. By determining the consensus and differences, the coefficient of consistency between the coders of Miles & Huberman (1994) was found to be 92%. A reliability calculation above 70% is considered reliable for research (Miles & Huberman, 1994). Accordingly, the study was considered reliable.

3. Results

3.1. Studies Conducted Based on the Prediction-Observation-Explanation in Biology Education

The aim of this research is to present a review of studies based on POE in biology education. Therefore, the results of the previous studies are presented chronologically, together with the sample selection and the methodology used in the studies. As a consequence of the literature review, it is seen that studies have been conducted in different disciplines regarding POE. It is noteworthy that the studies are mostly focused on physics and chemistry, and the number of studies on biology is less.

In the study of Köse, Coştu & Keser (2003), it was aimed to introduce the POE to researchers and teachers. In the study, researchers who prepared an exemplary activity on "Electromagnetism, Boiling and Photosynthesis" in accordance with this method in high school classrooms, also met with physics, chemistry and biology teachers and 86 high school students to determine the subjects on which the activities would be developed. As a consequence; it was concluded that the activities with the POE provided effective concept teaching and detected misconceptions.

Wu & Tsai (2005) examined the effect of POE on understanding "Biological Reproduction" with 69 fifth-grade students attending primary school in Taiwan. While POE activities-based constructivist were organized in the experimental group, traditional teaching was applied to the control group students. As a consequence; it was stated that POE activities improved students' understanding of the subject, enriched the information processing processes of the students, and contributed positively to the understanding of the experiments.

In the study of Demirelli et al. (2008), the effect of the application of the "Circulation System" subject with analogy and POE on achievement and attitude of 55 sixth-grade students was examined. The application was taught using the POE in one of the randomly selected classes, and the analogy method in the other. As a consequence; it was stated that there was no significant difference between the groups in which the POE and the analogy method were applied in terms of students' achievement and attitudes.

McGregor & Hargrave (2008) developed computer aided POE activities for the subject of photosynthesis in their study. The study sample consisted of 44 high school students. Achievement test as pretest and posttest was applied to control and experimental groups. As a consequence; it was stated that the average score of the achievement test of the students in the

experimental group with the courses conducted with the POE was higher than the students in the control group. Also, it was observed that students created mental conflicts while learning new concepts, and as a result, meaningful learning was achieved by comparing their predictions and observations.

Bilen's (2009) study conducted with 122 pre-service science teachers; the students in the experimental group were applied to the laboratory application based on the POE, and the students in the control group with the verification laboratory approach. Academic achievement test, scientific process skills test, attitude scale towards biology laboratory and nature of science questionnaire were used as data collection tools in the study. The data obtained as a result of the study; It has shown that the activities based on the POE have a significant effect on the conceptual achievement, the development of scientific process skills, their attitudes towards the biology laboratory and their views on the nature of science of pre-service science teachers. It was also revealed in the study that pre-service science teachers thought that the POE was time consuming and difficult, but described it as more enjoyable than other methods.

In the study of Özyılmaz-Akamca & Hamurcu (2009), the effect of teaching the subject of "The World of the Living Things" supported by analogies, concept cartoons and POE on achievement and attitudes was investigated. According to consequences; the scores obtained from the achievement test and the scale of attitude towards the course were analyzed and a significant difference was found in favor of the experimental group.

In the study of Bilen & Aydoğdu (2010), the impact of the activities based on POE on "Photosynthesis and Respiration in Plants" in the general biology laboratory on the conceptual achievements and attitudes of pre-service science teachers was investigated by comparing with the validation laboratory approach. The study was conducted with 122 second-grade students. As a consequence; it was seen that the activities based on the POE had a significant effect on the conceptual achievement and their attitudes towards the biology laboratory. With the application of POE, an increase was determined in both the achievement of the students and their attitudes towards biology laboratory.

Çinici & Demir (2010) applied collaborative and individual worksheets containing POE activities in their study, in which 30 ninth-grade students examined the effects of individual and cooperative POE activities on "Diffusion and Osmosis". According to the results, a statistically significant improvement was achieved in terms of academic achievement in both groups in which collaborative and individual worksheets were applied. It was determined that the students who were applied cooperative POE activities were statistically significantly more successful than the students who were applied individual POE activities.

In the study of Bilen, Köse & Uşak (2011), the effect of POE on teaching "Osmosis and Diffusion" subjects to 122 pre-service science teachers was examined. In the study, it was determined that the POE is more effective in teaching than the validation laboratory method. As a result, it was concluded that the POE is more efficient than traditional teaching methods. It has been concluded that it can be an effective method in detecting misconceptions as they have the opportunity to test their existing knowledge in the activities organized in accordance with the POE method in the biology laboratory of the pre-service science teachers.

In the study of Çinici, Sözbilir & Demir (2011) was planned to teach on 90 ninth-grade students the concepts of "Diffusion and Osmosis" in a meaningful way. In the study, the effects of cooperative and individual POE activities were examined. For this purpose, researchers have developed collaborative and individual worksheets that include POE activities on diffusion and osmosis. According to the results, a statistically significant improvement was achieved in terms of academic achievement in both groups in which cooperative and individual POE activities

were applied. It was determined that the students who were applied collaborative POE activities were statistically significantly more successful than the students who were applied individual POE activities.

In the thesis of Tokur (2011) on "The Growth and Development of Plants", the impacts of the experiments based on POE on conceptual achievement, scientific process skills, remembering and attitudes towards science were investigated. The study sample consisted of 80 pre-service primary teachers. As a consequence, it was stated that the conceptual achievement of the pre-service science teachers increased with the activity implementation based on the POE, their knowledge was more permanent and their attitudes towards science were positively affected.

In the study of Bilen & Köse (2012a) consisted of 144 pre-service primary teachers, the effect of POE on pre-service primary teachers' understanding of the subject of "Substance Transport in Plants" was examined. As a consequence; the pre-service primary teachers in the experimental group were found more successful than those in the control group in the achievement test based on the POE on "Substance Transport in Plants". Thus, it has been revealed that the activities based on the POE have a significant effect on the conceptual achievement of the pre-service primary teachers. Also, it was observed that pre-service primary teachers had some misconceptions about substance transport in plants and it was determined that the POE was effective in overcoming these misconceptions.

In the study of Bilen & Köse (2012b), the impacts of the experiments based on the POE in teaching the subject of "Growth and Development in Plants" on the conceptual achievement of pre-service science teachers and their attitudes towards science teaching were examined. The study sample consisted of 74 pre-service science teachers. The activities based on the POE were applied to the students in the experimental group, and the traditional teaching method was applied to the students in the control group. The study data were gathered by "Achievement Test" and "Science Teaching Attitude Scale". According to the consequences; it has been shown that the experiments based on the POE have a significant effect on the conceptual achievement of pre-service science teachers and their attitudes towards science teaching.

In the study of Karatekin & Öztürk (2012), the impact of the POE on "Cells and Tissues" on the achievement and scientific process skills of pre-service science teachers was examined. The study was conducted with 59 pre-service science teachers using a quasi-experimental design. As a consequence; it was stated that the POE positively contributed to the academic achievement and scientific process skills of pre-service science teachers.

In the thesis of Çetin (2013), he determined the effects of the activities with the POE on the achievement of students on "Respiratory System". In the study conducted with 67 seventh-grade students, it was found that POE activities created with animations had a significant effect on students' achievement in respiratory system.

In the study of Güven (2014), the impact of project-based learning method based on POE on the attitudes and behaviors of pre-service science teachers towards "Environmental Problems" was investigated. The study sample consisted of 93 pre-service science teachers. According to the consequences, it was stated that project-based learning method supported by POE positively changed pre-service science teachers' attitudes and behaviors towards environmental problems.

In the study of Harman (2014), the misconceptions of pre-service science teachers about "The Passage of Substances through the Cell Membrane" were determined with the POE. Experimental posttest design was used in the study without control group. The measurement tool, prepared in four parts, was applied to 89 pre-service science teachers. As a consequence;

it was stated that most of the pre-service science teachers gave correct information about the subject, however some pre-service science teachers had misconceptions. In addition, the pre-service teachers were made aware of their misconceptions about the subject, thanks to the activity.

In the study on "Sensory Organs" conducted by Göktürk (2015), 42 students from seventh-grade were divided into experimental and control groups. The experimental group was taught with the POE. As a consequence; It was observed that there was a statistically significant difference in favor of the experimental group according to the variables of academic achievement, attitude towards the course and permanence of the knowledge of the students.

In the study of Bilen, Özel, & Köse (2016), the effectiveness of action research based on POE on pre-service science teachers' understanding of "Enzymes" subject was examined. The sample of the study consisted of 80 pre-service science teachers. According to the concequences, it has been revealed that action research based on the POE increases the pre-service science teachers' understanding of enzymes. In addition, the results revealed that POE activities increased pre-services science teachers' interest in the science laboratory courses.

Güngör (2016) examined the effects of teaching biology subjects and concepts with POE on achievement, scientific process skills and permanence of pre-service science teachers. Concepts such as; biological diversity, population genetics, plant growth, digestion, enzymes, germination, hormones and respiration were applied with the teaching method based on POE in the study. The study sample consisted of 75 pre-service science teachers. As a consequence; It was stated that the activities based on POE had a statistically positive effect on the development of scientific process skills and conceptual achievement of pre-service science teachers.

Kozcu-Çakır, Güven & Özdemir (2017) examined the effect of applying the POE to the General Biology Laboratory course on the academic achievements and scientific process skills of pre-service science teachers. "POE form" and "Achievement Test" were applied to 58 pre-service science teachers. The study consisted of "Photosynthesis and Respiration" subjects. As a result, it was stated that there was a positive increase in the scientific process skills and success of the pre-service science teachers which was taught with the support of the POE.

Güngör & Özkan (2017) aimed to teach the relationship between light and auxin, one of the growth hormones in plants, using the POE. The study sample consisted of 32 pre-service science teachers. As a consequence, it has been revealed that effective use of this teaching further increases the participation of pre-service teachers in the course.

In the study of Widiyaningrum, Bintari & Rahayuningsih (2018), in which 180 seventh-grade students participated, the effect of teaching fungi with the POE in the laboratory environment on students' participation in the course was examined. As a consequence; it was understood that there were positive developments in students' understanding of the subject, participation in the lesson and lesson motivation.

In the study of Fitriani, Zubaidah, Susilo & Al Muhdhar (2020), the effects of Problem Based Learning (PBL), POE and the combination of both (PBLPOE) on students' critical thinking skills and scientific attitudes in Biology were investigated. The study sample consisted of 132 tenth-grade students from Indonesia. The study consists of "Plants, Animals, Ecosystem and Environmental Pollution" subjects. As a consequence, it was stated that PBL, POE and PBLPOE have an impact on students' attitudes and critical thinking skills in Biology. It has been determined that PBLPOE is not significantly different from PBL, but is significantly different from POE and traditional in developing students' critical thinking.

In the study of Güleşir, Aydemir, Kuş, Uzel & Gül (2020), some experiments within the scope of physiology subjects were applied with the POE and the prediction, observation, explanation, scientific process skills of pre-service biology teachers were investigated. Data were collected using "POE worksheets". The study sample consisted of 12 pre-service biology teachers. As a consequence; it was stated that teaching based on POE within the scope of physiology subjects improved the scientific process skills of pre-service biology teachers. In addition, when the responses of the pre-service biology teachers to the POE worksheets were examined, it was determined that they had misconceptions about "plasmolysis and deplasmolysis", "transfer of substances" and "photosynthesis". Therefore, it has been suggested that the POE method can be used as an alternative assessment method.

In his master's thesis, Kasım (2020) determined the impact of outdoor education activities supported by the POE on students' learning permanence and academic achievement. In a study conducted with 62 fifth-grade students, it was stated that in the teaching of the subject of "Recognize the Living Creatures", outdoor education activities supported by POE had a positive effect on academic achievement and learning permanence of students.

Prabawati, Nugrahaningsih & Alimah (2020) aimed to teach the excretory system with the POE in their study. The study sample consisted of 46 eleventh-grade students. As a consequence; it was observed that the learning process using the POE increased the learning outcomes of the students.

3.2. The Responses to the Research Problems

In the research, the findings obtained from the studies in which the POE was used in biology education were presented. Within the scope of the research, the analyzes of the sampled studies were shown in graphs and tables. The first research problem is "What is the research type of the studies examined?" determined as. In this context, the distribution of the investigated studies by research type has been examined and presented in Table 3.

Table 3. *Distribution of studies in terms of research type*

Research Type	Frequency	%
Article	21	77.77
Master Thesis	5	18.51
Doctoral Dissertation	1	3.70
Total	27	100

According to Table 3, it is stated that the studies are distributed as 21 studies, 5 master theses and 1 doctoral dissertation in terms of research type. Of the total research, 78% is articles, 19% master theses and 4% doctoral dissertations.

The second research problem is "What is the distribution of the examined studies by years?" determined as. The distribution of the examined studies according to the years of publication has been presented in Figure 1.

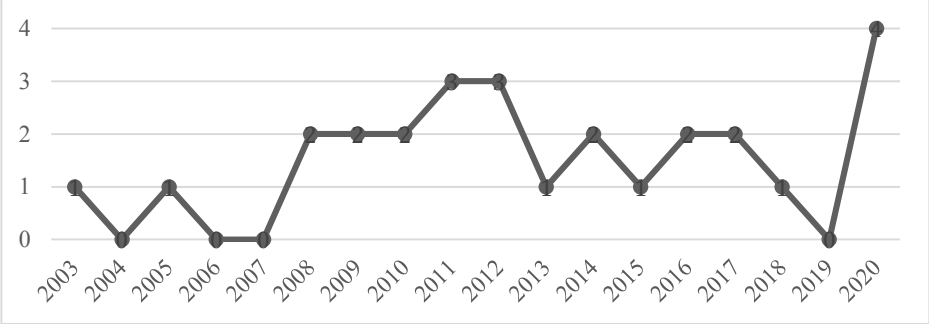

Figure 1. Distribution of studies by publication years

According to Figure 1, it is stated that the studies using the POE in biology education have been one research since 2003, and more than one study since 2008. It is observed that the highest number of studies is 4 studies in 2020, then 3 studies in 2011 and 2012. It was stated that the least number of studies were in 2003, 2005, 2013, 2015 and 2018 with one study.

The third research problem is "Which are the preferred research groups in the studies examined?" determined as. According to the studies examined, the preferred research groups are; pre-service teachers, middle school students and high school students. The frequency and percentage values for these research groups are presented in Table 4.

Table 4. *Preferred research groups*

Research Groups	**Frequency**	**%**
Pre-service Teachers	14	51.85
Middle School Students	7	25.93
High School Students	6	22.22
Total	27	100

According to Table 4, it is observed that the most pre-service teachers were selected as the research group in the studies using the POE in biology education. This is followed by middle school and high school students, respectively.

The fourth research problem is "What are the research methods used in the studies examined?" determined as. Research methods in the examined studies are grouped as quantitative, qualitative and mixed methods. The frequency and percentage values for these research methods are presented in Table 5.

Table 5. *Distribution of research methods used*

Research Method	**Frequency**	**%**
Quantitative	15	55.55
Mixed	7	25.92
Qualitative	5	18.51
Total	27	100

According to Table 5, it is stated that the most quantitative research methods are chosen in the studies using the POE in biology education. This is followed by mixed and qualitative research methods, respectively.

The fifth research problem is "What are the data collection tools used in the studies examined?" determined as. The frequency and percentage values of the data collection tools used in the studies are presented in Table 6.

Table 6. *Distribution of data collection tools used*

Data Collection Tools	Frequency	%
Academic Achievement Test	18	36.73
Attitude Scale	12	24.48
POE Worksheets	7	14.28
Scientific Process Skills Test	6	12.24
Interview	3	6.12
The Nature of Science Scale	1	2.04
Critical Thinking Scale	1	2.04
Misconception Test	1	2.04
Total	49	100

According to Table 6, it is stated that in studies using POE in biology education, academic achievement tests are mostly used as data collection tools. This is followed by attitude scale, POE worksheets and scientific process skills test, respectively.

The sixth research problem is "In which subject areas were the studies examined?" determined as. The frequency and percentage values of the subject areas included in the examined studies are presented in Table 7.

Table 7. *Distribution of the subject areas of the studies*

Subject Areas	Frequency	%
Diffusion-Osmosis	7	13.20
Photosynthesis	6	11.32
Growth and Development in Plants	6	11.32
Cell-Tissue	3	5.66
Enzymes	3	5.66
Biological Diversity	3	5.66
Cellular Respiration	3	5.66
Plasmolysis-Deplasmolysis	2	3.77
Transport in Plants	2	3.77
Animals	2	3.77
Fungi	2	3.77
Hormones	2	3.77
Environmental Problems	2	3.77
Microscope	1	1.88
Circulatory System	1	1.88
Sense Organs	1	1.88
Respiratory System	1	1.88
Ecosystem	1	1.88
Population Genetics	1	1.88
Excretory System	1	1.88
Digestion	1	1.88
Microorganisms	1	1.88
Biological Reproduction	1	1.88
Total	53	100

As a result, obtained from the studies examined, it was determined that 53 subject areas were studied. According to Table 7, it is stated that the studies using the POE are mostly carried out in the "Diffusion-Osmosis" subject. This is followed by "Photosynthesis, Growth and Development in Plants, Cell-Tissue, Enzymes, Biological Diversity and Cellular Respiration", respectively.

4. Discussion and Conclusion

In this research; studies using of the POE in biology education between the years 2000-2020 in Turkey and the World have been examined considering certain criteria. For this purpose, 27 studies in the literature were reached. It is stated that the distribution of studies in terms of research type is as 21 article, 5 master thesis and 1 doctoral dissertation. As a consequence of this research, it was identified that the number of studies on the use of the POE in biology education between the years 2000-2020 varied by years. It was determined that the most studies were conducted in 2020.

In the studies examined, it is stated that mostly pre-service teachers who continue their undergraduate education are selected as the study group. This research finding overlaps with the data obtained from previously reviewed articles (Çiltaş, Güler, & Sözbilir, 2012; Selçuk et al., 2014). The reason why undergraduate students are mostly preferred as the study group may be that the undergraduate student group is more easily accessible to researchers in the field. It is an important deficiency that the secondary and high school levels, where meaningful learning of basic concepts in the field of biology is most necessary, has not been studied sufficiently. It is considered important for the variety of research and results that researchers conduct studies, including middle school, high school, and even graduate student groups.

In the studies examined, it was determined that quantitative research methods were used most. The reason why quantitative research method is preferred more is thought to be the ability to collect and interpret research data in a short time. In 5 of the investigated studies, qualitative research methods were preferred. Conducting case studies rather than qualitative research designs in studies is thought to be preferred because it allows researchers to examine one or more events and environments in depth (McMillan, 2000). The reason why mixed studies are preferred among the research types may be that the mixed method enables the use of qualitative data to explain the quantitative data obtained (Leavy, 2017). This method enables both qualitative data and quantitative data to be collected by questioning, to integrate quantitative and qualitative data, to use the philosophical assumptions and theoretical frameworks of both together. In this way, the researcher will present a more holistic perspective. In this context, collecting both qualitative and quantitative data contributes a better understanding of the research problem (Axinn, Fricke & Thornton, 1991; Leavy, 2017).

In the studies examined, it is observed that the academic achievement test is the most preferred data collection tool. The most preferred data collection tools are attitude scale and POE worksheets after the academic achievement test. Because patterns of achievement are difficult to assess, most researchers have relied on a narrower definition that is largely limited to the results of standardized achievement tests (Lindholm-Leary & Borsato, 2006). In addition, it is another finding obtained from studies in which more than one data collection tool was used in each study. Thus, it is stated that there is diversity in data collection tools (Yıldırım & Şimşek, 2008). It is very common to use the achievement test as pretest and posttest in experimental studies (Çardak & Selvi, 2018). Considering the fact that most of the studies are experimental, it is observed that data collection tools are compatible with experimental studies in this direction. Research has revealed that the POE technique contributes greatly to students'

conceptual understanding. When examined in other studies on the POE, it is determined that conducting the teaching process with activities based on the POE provides meaningful learning and significantly increases academic achievement (White & Gunstone, 1992; Liew & Treagust, 1998; Kearney, 2002; Acar-Şeşen & Mutlu, 2016).

Considering the subject areas of the studied studies, it has been determined that they are mostly carried out in "Diffusion-Osmosis, Photosynthesis and Growth-Development in Plants". The common point of these subject areas is that they require practice based activities. Studies show that "Diffusion and Osmosis" concepts are not fully understood by students and are perceived as difficult by students (Çinici, Sözbilir & Demir, 2011; Sanger, Brecheisen, & Hynek 2001). Similarly, the subject of "Photosynthesis" has been considered as one of the most difficult subjects for students to understand (Stavy, Eisen & Yaakobi, 1987). Students are thought to have difficulty because they cannot understand the connections between many conceptual aspects of photosynthesis, such as physiological and biochemical (Waheed & Lucas, 1992). Additionally, it has been found that students have found research that they have difficulty understanding some basic concepts related to "The Growth-Development in Plants" (Barman, Stein, McNair & Barman, 2006). The reason why researchers prefer these subject areas may be that the expert knowledge of the researchers determines the subject on which the research will be conducted and it is thought that students have more misconceptions in these subject areas.

According to the constructivist learning theory; for an effective education, students should be guided to express their opinions in the educational process (Prediction stage), students should be faced with situations that contradict their own opinions (Observation stage), students should be encouraged to create hypotheses and offer alternative interpretations to events (Prediction and Explanation stages), especially students should be given the opportunity to think of alternative ideas (Explanation stage), and students should be given the opportunity to use new ideas in various situations in order to understand the benefits of new ideas (Driver & Bell, 1986). In this context, the principles of constructivist learning theory for an effective education can be easily applied with the use of POE (Köseoğlu, Tümay & Kavak, 2002). In this context, the POE method is effective for students to make permanent the knowledge they have learned within the scope of science lesson and especially the biology lesson, which is closely related to daily life, and to use this knowledge both in the educational environment and in daily life. Considering all these features, it is predicted that the POE will be beneficial for teachers in the application of the teaching process. As a consequence of the literature's review, it is striking that the studies using the POE are mostly in the fields of physics and chemistry, and the scarcity of research in the field of biology (Güngör, 2016). For this reason, more emphasis on biology topics based on the POE in research will ensure that the requirements of the constructivist approach are fulfilled.

When the results of the studies conducted with POE between the years 2000-2020 are examined, it is seen that the sample groups applied with the POE are generally more successful than the groups that are taught with traditional methods. In addition, it was concluded that the active participation of the learners was ensured in the lessons and practices conducted with POE. Again, in these studies, it was determined that learners developed a positive attitude towards the activities carried out with the POE. For this reason, it is important that POE, which has such a high efficiency, is widely used in biology education, also. In addition, the use of POE, which is developed according to the constructivist learning theory to ensure permanent learning, for biology subjects that students find difficult to understand and boring will make the course productive. It is thought that the data obtained from this research will contribute to revealing the research trend in the field of biology education and to give an idea to the researchers for their studies with POE.

5. Conflict of Interest

The author declares that there is no conflict of interest.

6. Ethics Committee Approval

The author confirm that the study does not need ethics committee approval according to the research integrity rules in their country.

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