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RESEARCH ARTICLE

Teaching the Concepts of Photosynthesis and Cellular Respiration Through Prediction–Observation–Explanation Technique During Distance Education for Secondary School Students' Academic Achievement and Scientific Process Skills Evaluation

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Abstract

In this research, it is aimed to examine the effect of teaching photosynthesis and cellular respiration technology-supported prediction–observation–explanation technique through distance education on eighth-grade secondary school students' academic achievement and scientific process skills. In the research, a pretest–posttest quasi-experimental design with control group was used. The participants of the research consist of 40 eighth-grade students studying in a secondary school in İstanbul. Experimental and control groups were determined by random assignment. The teaching of the subjects was carried out with technology-supported prediction-observation-explanation activities developed by the researchers in the experimental group. In the control group, the teaching of the subjects was carried out with the activities in the eighth-grade science coursebook. In the research, "Photosynthesis and Respiration Achievement Test" and "Scientific Process Skills Scale" were used as data collection tools before and after the learning process. The data obtained in the research were evaluated with the SPSS package program. According to the results, a significant difference was found in favor of the experimental group in terms of academic achievement and scientific process skills.

Keywords: Distance education, photosynthesis and cellular respiration, prediction-observation-explanation (POE), science education, scientific process skills

Introduction

Corona virus disease 2019 (COVID-19), which first appeared on December 1, 2019, in Wuhan, China, has affected the whole world. In many countries, it has affected areas such as the economy, psychology, social, health, and education. The COVID-19 pandemic has affected the education system worldwide, causing schools and universities to suspend education and even to close. In this process, applications such as live courses, Zoom, Teams, and Skype have started to be used for conducting the lessons in order to make the education continuous and not to interrupt the education of the students (Ayaz, 2021; Can, 2020). With these applications, the transition to distance education has been ensured all over the world and technology, which has become increasingly important for courses today and has begun to take place more and more. Today, with the development of technology, communication methods and forms of education are changing. In regions where communication technologies are not developed or cannot be used effectively, while education depends on the time and place where individuals must be together, the effects of time and place on education have decreased with the development of technology. Thus, these new communication technologies have led to the emergence of new forms of education. Distance education is the most widely used education model among the education forms. During the COVID-19 pandemic process, it was possible to carry out education without interruption, thanks to distance education. With the first case seen in our country, education was interrupted. Therefore, distance education was started at all levels by the Ministry of National Education so that students would not be deprived of education in this process.

Distance education, structured learning in which the student and instructor are separated by place and sometimes by time, is currently the fastest growing form of domestic and international education. What was once considered a special form of education using nontraditional delivery systems, is now becoming an important concept in mainstream education (Gunawardena & McIsaac, 2003). In the distance education process, students and teachers physically connect with teaching resources and interactive communication technologies in separate environments (Burke & Dempsey, 2020; Doghonadze et al., 2020; Simonson et al., 2012). Distance education has conceptual aims such as creating new educational opportunities, integrating work and teaching, providing equal opportunities in education, providing lifelong learning, integrating educational technology into the process, providing individual and mass education opportunities, and making education effective, efficient, and cost-effective (Cavanaugh, 2001). In addition, distance education is a method that provides education and training opportunities to students by using printed, audio-visual, and electronic materials

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when there is no education opportunity in formal education institutions due to various reasons such as illness, geographical distance, family situations, time, and money problems (Demiray, 1999). Distance education could be conducted either simultaneously or asynchronously. In simultaneous learning, the teacher and the learner are in the learning environment at the same time. This model was described as synchronous distance learning. In asynchronous distance learning, it is possible for the teacher and the learner to be in the learning environment at different times (Zhang & Nunamaker, 2003). Popularization of distance education and digital literacy in 2020 due to the global impact of the COVID-19 pandemic required novel studies on self-regulated learning environments. Digital educational environments where learners control their own learning experiences, reflect on self-learning, and take the responsibility to learn became prominent (Erol, 2020).

Technology needs to be understood and used correctly. In addition, the integration of technology into education continues. Therefore, technology is an important part of education. In today's conditions, many technological tools are used to meet the needs of science education. Among these, the technology-supported teaching approach stands out. With the transition to distance education during the COVID-19 pandemic process, technology has come to the fore and played an important supporting role in education (Chang et al., 2022). In order to meet the needs of students and to bring technology to the fore with distance education, it is necessary to prevent mere technology by making instructional designs to support meaningful learning (Bozkurt, 2020). One of the problems frequently encountered in science teaching in the distance education process is laboratory applications (Das, 2010, Nancheva & Stoyanov, 2005). It is not easy to implement laboratory studies in the distance education process. For this, different methods and techniques need to be developed and there is a need to use information and communication technology tools (Das, 2010). In this context, virtual reality-based simulation applications aim to provide environments that will motivate students and facilitate perception through the distance education process (Chun et al., 2002). These simulations are also effective in laboratory applications (Rutten et al., 2012; Şahin, 2006). Simulations create opportunities for broader learning by bringing students face to face with concepts for the purpose of questioning. Thus, incorrect learning is prevented. Simulations are represented by intuitive concepts of phenomena in which students experience contradictions. Laboratory activities supported by simulation create a functional benefit in concept development (Gülçiçek & Güneş, 2004).

In the 21st century, when science is very important, the science curriculum has adopted a vision aimed at raising individuals who are well-equipped, who are researchers, who question, who know themselves and their environment, who use scientific process skills, and who raise awareness about technological development (MEB, 2018). In addition to the students' production of scientific knowledge, methods, techniques, and practices are used to enable them to reach information by using scientific thinking and scientific process skills in their daily lives. One of the techniques that enables students to create scientific knowledge with their own research and inquiries in line with their scientific process skills is the prediction–observation–explanation (POE) technique (Tokur, 2011). This technique, presented in detail by White and Gunstone (1992), is based on a principle in which students first make a prediction about a show, experiment, or a topic to be presented, together with the reason, then observe the event and explain the prediction and observation together (Kearney & Treagust 2000; White & Gunstone, 1992). In this context, the POE technique is applied in three stages: prediction, observation, and explanation. In the first stage of the POE technique, after giving information to the students about a demonstration, experiment, or event, they are asked to make predictions based on the result of the demonstration, experiment, or event and to explain the reasons for their predictions. In the second stage, the observation stage, the students are presented with the demonstration, experiment, or event that they predicted. In the third stage, the explanation stage, students are asked to discuss the similarities and contradictions between their predictions and observations and to resolve these contradictions, if any (Akdeniz et al., 2014; Yulianti et al., 2018). In this respect, POE is a technique that contributes to students being active in the learning process, expressing their opinions, and making connections between their prior knowledge and new knowledge (Kearney & Treagust, 2000; Yulianti et al., 2018). Prediction–observation–explana tion technique is more effective than other techniques in that students can realize their prior knowledge by writing their guesses with their justifications, and in the explanation stage, they can reach the information themselves and learn the subjects more easily (Durmuş, 2014). It can be thought that the technology-supported POE technique used in the present research encourages students to think in different ways and contributes positively to the organization of information (Karadeniz, 2019). Technology-supported POE activities also contribute to the development of students' ability to interpret and analyze, predict, and reason (Ulfa et al., 2017). Although the concepts taught since primary school are desired to be permanent for a long time, it is seen that very basic science concepts are not known in the university environment and most of the students forget the concepts after memorizing them until they pass the exam. Simulation and animation applications should be included in order to transfer science teaching to daily life in distance education (Ayaz, 2021), and the subject should be connected with daily life with simple explanatory problems and made concrete (Şahin & Oktay, 1996). Most of the research on distance education has focused mostly on theoretical courses in order to determine the views of teachers and students. In this sense, the application of technology-supported POE activities carried out in distance education in the science course, which is a practice-based course, for teaching photosynthesis and cellular respiration, which is among the subjects that are considered difficult to understand during the pandemic period, reveals the importance of this research as it is a subject that has not been researched before. In this research, it was also examined how effective the teaching of secondary school students with technology-supported POE activities during the epidemic process could be. In this research, it was examined how technology-supported POE activities for the subject of photosynthesis and cellular respiration in science courses have been developed and how it changed their understanding of the subject by looking at the effect of POE on secondary school students' academic achievement and scientific process skill levels. For this purpose, technology-supported POE activities are used. The research question of this study is what is the effect of teaching photosynthesis and cellular respiration concepts through technology-supported POE activities during distance education on eighth-grade students' academic achievements and scientific process skills. For this purpose, the sub-problems of the research were determined as follows:

1. Is there a significant difference between the academic achievements of the students in the experimental group, in which the technology-supported POE activities related to photosynthesis and cellular respiration were applied, and the students in the control group, in which the activities in the science coursebook were applied?
2. Is there a significant difference between the scientific process skills of the students in the experimental group, in which the technology-supported POE activities related to photosynthesis and cellular respiration were applied, and the students in the control group, in which the activities in the science coursebook were applied?

Method

Research Method

In this research, quantitative analysis methods were used to evaluate the measurement tools used to investigate the effects of

Table 1.
Experimental Design of the Research

Group	Data Collection Tools Before Application	Method	Data Collection Tools After Application
Experimental	PRAT SPSS	Technology-supported POE technique	PRAT SPSS
Control	PRAT SPSS	With the activities in the science coursebook approved by the Ministry of National Education for the 2020–2021 academic year	PRAT SPSS

Note: PRAT = Photosynthesis and Respiration Achievement Test; SPSS = Scientific Process Skills Scale.

technology-supported POE activities applied through distance education on the academic achievement and scientific process skills of eighth-grade secondary school students. In the research, a pretest–post-test quasi-experimental design with control group was used. In the experimental group, the subjects of "photosynthesis and cellular respiration," which are included in the subject of "energy transformations" in the "energy conversions and environmental science" unit of the eighth-grade science course, were taught with technology-supported POE activities developed by the researcher. In the control group, the activities in the eighth-grade science coursebook used in the 2020–2021 academic year were carried out in accordance with the science curriculum. The experimental design of the research is presented in Table 1.

Participants

The study group of the research consists of eighth-grade students studying in a secondary school in Fatih District of İstanbul Province. In the 2020–2021 academic year, two branches from the eighth grades were randomly selected for the purpose of conducting the research. Since it is difficult to reach the samples due to the pandemic conditions we are in, the study was carried out with the classes that can be reached in cooperation with the school administration. For this reason, it has not been possible to work in groups whose achievement and scientific process skill levels are equivalent. The research was carried out with total 40 students in the experimental and control groups. The frequencies and percentages related to the experimental and control groups and gender variables related to the study group are given in Table 2.

Table 2.
Diagnostic Information of the Research Groups

	N		Girl		Boy	
Group	**f**	**%**	**f**	**%**	**f**	**%**
Experimental	20	50	11	55	9	45
Control	20	50	12	60	8	40

Experimental Procedure

The study was carried out during 5 weeks and 10 lesson hours (1 lesson is 40 minutes). The POE activities were reviewed by two science teachers, and learning process in two groups was designed through their feedbacks. The application process of technology-supported POE activities in the experimental group is presented in Table 3.

Before the applications, the Photosynthesis and Respiration Achievement Test (PRAT) and Scientific Process Skills Scale (SPSS) pretests were administered by the researcher to the students via the Google form. In the research, six POE activities on subjects related to misunderstood concepts that students have difficulty in understanding about photosynthesis and cellular respiration were sent to students via email and mobile applications (WhatsApp and Zoom) for 4 weeks. Technology-supported teaching was used for the implementation of the activities. The activities were carried out with the students through the Zoom program. With the Zoom program, web-supported simulation, animation, and video contents were screen-shared and applied to the students in order according to the steps specified in the POE activities. Students were asked to write the POE parts in their own sentences during the activity.

Prediction–observation–explanation activities consist of three parts: prediction, observation, and explanation. In POE activities, video images, simulations, and animations were used and presented to the students during the observation stage. Worksheets specific to each activity were prepared in which students could write their predictions, reasons for their predictions, observations, and differences between their predictions and observations in each activity, and these papers were sent to the students before the activities. In the explanation stage, it was questioned whether their predictions were correct or not, and the students were asked to answer them. When the activities were completed, the students sent their work to the researcher in a short time via email and mobile applications (e.g., WhatsApp).

Table 3.
Implementation Process of the Activities in the Experimental Group

Week	Time	Date	Application Stages
1	2 hours	April 2, 2021	Application of PRAT and SPSS pretests Introduction of POE technique Giving information on how the activities will be implemented
2	2 hours	April 9, 2021	Implementation of the first activity and writing the activities done by the students on the worksheet and then collecting them Implementation of the second activity and writing the activities done by the students on the worksheet and then collecting them
3	2 hours	April 16, 2021	Implementation of the third activity and writing the activities done by the students on the worksheet and then collecting them Implementation of the fourth activity and writing the activities done by the students on the worksheet and then collecting them
4	2 hours	April 23, 2021	Implementation of the fifth activity and writing the activities done by the students on the worksheet and then collecting them Implementation of the sixth activity and writing the activities done by the students on the worksheet and then collecting them
5	2 hours	April 30, 2021	Application of PRAT and SPSS post-tests

Table 4.
Implementation Process of the Activities in the Control Group

Week	Time	Date	Application Stages
1	2 hours	April 1, 2021	Application of PRAT and SPSS pretests Examining students' prior knowledge about photosynthesis Asking for examples from daily life
2	2 hours	April 8, 2021	Checking the students' prior knowledge about the importance of photosynthesis in food production in plants, asking for examples from daily life Conducting the lesson in the form of questions and answers with the presentation method and taking notes Having an imbalance between prior knowledge and newly learned knowledge
3	2 hours	April 15, 2021	Examining students' prior knowledge about productive organisms Questioning whether photosynthetic organisms are producers, asking for examples from daily life Conducting the lesson in the form of questions and answers with the presentation method and taking notes Having an imbalance between prior knowledge and newly learned knowledge
4	2 hours	April 22, 2021	Using the question–answer method about how respiration occurs in living things Using the method of discussion about the difference and similarity of respiratory functioning from plant and animal cells Examining students' prior knowledge and opinions about the difference between respiration and photosynthesis Talking about breathing types, asking for examples from daily life Conducting the lesson in the form of questions and answers with the presentation method and taking notes Having an imbal-ance between prior knowledge and newly learned knowledge
5	2 hours	April 29, 2021	Application of PRAT and SPSS post-tests

On the other hand, the subjects of "photosynthesis and cellular respiration" were taught to the control group with the activities in the science coursebook. The students' prior knowledge was checked and a relationship was established between the newly learned concepts and words, and it was ensured that the students questioned and doubted the existing concepts. The lessons of the control group were carried out with a presentation by following the science coursebook through the Zoom program through distance education. The studies were applied to the control group as 5 weeks and 10 lesson hours. Before the applications, the PRAT and SPSS pretests were administered by the researcher to the students via the Google form. The implementation process of the activities in the control group is presented in Table 4.

Data Collection Tools

Photosynthesis and Respiration Achievement Test (PRAT)

In the research, the "PRAT" developed by Dilek (2006) was used to determine the academic achievement of eighth-grade secondary school students in the subjects of "photosynthesis and respiration." The test, which is compatible with the eighth-grade science curriculum and the contents of photosynthesis and respiration, consists of 20 multiple-choice questions. The α reliability of the test was found to be 0.72. In this research, the α reliability value of the test was determined as 0.80.

Scientific Process Skills Scale (SPSS)

The "Scientific Process Skills Scale" developed by Aydoğdu et al. (2012) was used to measure the scientific process skills of the experimental and control group students. The test is used to reveal students' ability to solve various problems that they may encounter, especially in science and mathematics lessons. Scientific Process Skills Scale consists of 27 multiple-choice items with 4 options designed to measure basic skills and high-level skills. The reliability of the scale (KR-20) was calculated as 0.84.

Data Analysis

The statistical analysis of the data obtained from the research was made with Statistical Package for the Social Sciences software program. Kolmogorov–Smirnov test was used to see whether the data distribution was normal before the difference between arithmetic means was tested (Akgül, 2005). The p-value calculated with Kolmogorov–Smirnov test being smaller than $p < .05$ shows that at this level of significance, scores show a significant deviation from the normal distribution (Büyüköztürk, 2019).

Since the data did not show normal distribution ($p < .05$), non-parametric Mann–Whitney U test was used for independent samples and Wilcoxon-signed ranks test was used for dependent samples. The formula $r = Z/\sqrt{N}$ was used to calculate the effect of Mann–Whitney U and Wilcoxon-signed ranks test results (N = number of people in the pretest + number of people in the post-test) (Büyüköztürk, 2019). In the interpretation of the effect size of the results, the effect size classification suggested by Cohen (1988) ($r = .10$ small, $r = .30$ medium, and $r = .50$ large effect) was taken into account (Büyüköztürk, 2019).

Results

Findings of the First Sub-problem

"Is there a significant difference between the academic achievements of the students in the experimental group, in which technology-supported POE activities prepared for the subjects of photosynthesis and cellular respiration were applied via distance education, and the students in the control group, in which the activities in the science coursebook were applied via distance education?" In order to find an answer to the first sub-problem, PRAT was applied to the experimental and control group students before and after teaching the subjects of "photosynthesis and cellular respiration."

PRAT Pretest–Post-test Normal Distribution Findings of Experimental and Control Groups

Since the sample size of the experimental and control groups was smaller than 30, the PRAT normal distribution was determined by Kolmogorov–Smirnov test (Table 5).

As seen in Table 5, the pretest–post-test scores obtained from the PRAT are not normally distributed in the (*) marked line ($p < .05$), while the other lines are normally distributed ($p > .05$). Therefore, it

Table 5.
Pretest–Post-test PRAT Kolmogorov–Smirnov Test Results of Experimental and Control Groups

Group	Statistics	f	p
Pretest of the experimental group	.144	20	.20
Pretest of the control group	.146	20	.20
Post-test of the experimental group	.136	20	.20
Post-test of the control group	.208	20	.023*

*$p < .05$.

Table 6.
PRAT Pretest–Post-test Descriptive Statistics Results of Experimental and Control Groups

Group	*N*	Mean	SD	Min.	Max.
Pretest of the experimental group	20	11.25	3.24	4.00	17.00
Post-test of the experimental group	20	16.45	2.11	13.00	20.00
Pretest of the control group	20	8.90	3.91	3.00	17.00
Post-test of the control group	20	9.65	3.78	3.00	18.00

was accepted to use non-parametric statistical methods in the analysis of data obtained from PRAT.

PRAT Pretest–Post-test Descriptive Statistics Results of Experimental and Control Groups

Descriptive statistics were used to determine the mean scores of the experimental group before and after the technology-supported POE activities and the mean scores of the control group before and after the science coursebook activities application. The obtained results are given in Table 6.

Experimental and Control Groups PRAT Pretest Findings

Photosynthesis and Respiration Achievement Test consisting of 20 items was applied as a pretest to 40 students in the experimental and control groups. The highest score that can be obtained from the test is 20. The Mann–Whitney *U* test findings, which were used to test the significance of the difference between the PRAT pretest scores of the experimental and control groups, are given in Table 7.

When Table 7 is examined, it is seen that there is a significant difference between the experimental and control groups according to the PRAT pretest ($U=126.500$, $z=-2.004$, $p < .05$). A statistically significant difference was found between the PRAT pretest scores of the experimental and control group students in favor of the experimental group ($p < .05$). According to this result, the academic achievements of the two groups regarding photosynthesis and cellular respiration are different from each other. The prior knowledge of the experimental and control groups is different from each other. The effect size of the PRAT pretest was found to be ($r=.31$). The pretest of PRAT shows that students' academic achievement has a moderate effect before POE technique.

Experimental and Control Groups PRAT Post-test Results

The Mann–Whitney *U* test was used to determine between which groups the post-test PRAT average scores of the experimental and control groups differed. The data obtained are presented in Table 8.

When Table 8 is examined, it is seen that there is a significant difference between the experimental and control groups ($U=20.500$, $z=-4.875$, $p < .05$). A statistically significant difference was found between the PRAT post-test scores of the experimental and control group students in favor of the experimental group ($p < .05$). According to this result, the achievement levels of the two groups regarding photosynthesis and cellular respiration are different from each other. The knowledge levels of the experimental and control groups differ from each other. The effect value size of the PRAT post-test was found to be ($r=.77$). A statistically significant difference was found in favor of the experimental group between the academic achievement post-test scores of the experimental and control group students in the subjects of "photosynthesis and cellular respiration" ($p < .05$). The post-test of PRAT shows that the application of the POE technique has a high level of effect on the academic achievement of students. Accordingly, it is seen that the technology-supported POE technique is effective in increasing academic achievement.

PRAT Pretest–Post-test Findings

Considering the descriptive statistics results in Table 6, it was determined that the average score obtained by the students from the PRAT pretest increased from 11.25 to 16.45 after the application. The Wilcoxon-signed rank test results are given in Table 9 to determine the significance of this increase in the pretest–post-test mean scores of the students.

When the results obtained from Table 9 are examined, it is seen that there is a significant difference ($Z=-4.338$, $p < .05$, $r=.68$) between the pretest–post-test rank averages. Considering the effect size, it was concluded that the application of POE activities had a high level of effect on academic achievement. When the mean rank and totals of the difference scores are taken into account, it is seen that this observed difference is in favor of the positive ranks, that is, the post-test score. According to these results, it is seen that technology-supported POE activities are effective in the academic achievement of students.

Findings of the Second Sub-problem

"Is there a significant difference between the scientific process skills of the students in the experimental group, in which technology-supported POE activities prepared for the subjects of photosynthesis and cellular respiration were applied via distance education, and the students in the control group, in which the activities in the science coursebook were applied via distance education?" In order to find an answer to the second sub-problem, the SPSS was applied to the experimental and control group students before and after teaching the subjects of "photosynthesis and cellular respiration."

SPSS Pretest–Post-test Normal Distribution Findings of Experimental and Control Groups

Due to the sample size of the experimental and control groups being smaller than 30, it was determined that SPSS showed normal distribution with the Kolmogorov–Smirnov test (Table 10).

Table 7.
Mann–Whitney U Test Results of the Difference Between Experimental and Control Groups PRAT Pretest Scores

Group	N	Mean Rank	Sum of Ranks	*U*	*z*	*p*	*r*
Experimental	20	24.18	483.50	126.50	−2.004	.045*	.31
Control	20	16.83	336.50				

*$p < .05$.

Table 8.
Mann–Whitney U Test Results of the Difference Between Experimental and Control Groups PRAT Post-test Scores

Group	*N*	Mean Rank	Sum of Ranks	*U*	*z*	*p*	*r*
Experimental	20	29.48	583.50	20.50	−4.875	.000*	.77
Control	20	11.53	230.50				

*$p < .05$.

Table 9.
PRAT Pretest–Post-test Wilcoxon-Signed Ranks Test Results

Pretest–Post-test	*n*	Mean Rank	Sum of Ranks	*z*	*p*	*r*
Negative rank	3	14.83	44.50	-4.338	.00*	.68
Positive rank	31	17.76	550.50			
Ties	6					

*$p < .05$.

Table 10.
SPSS Pretest–Post-test Kolmogorov–Smirnov Test Results of Experimental and Control Groups

Group	Statistics	f	*p*
Pretest of the experimental group	.253	20	.002*
Pretest of the control group	.190	20	.055
Post-test of the experimental group	.156	20	.200
Post-test of the control group	.248	20	.002*

*$p < .05$.

Table 11.
SPSS Pretest-Post-test Descriptive Statistics Results of Experimental and Control Groups

Group	*N*	Mean	SD	Min.	Max.
Pretest of the experimental group	20	16.95	5.96	3.00	23.00
Post-test of the experimental group	20	17.60	4.44	7.00	23.00
Pretest of the control group	20	13.15	6.00	4.00	22.00
Post-test of the control group	20	14.00	5.78	4.00	20.00

As can be seen in Table 10, in the pretest–post-test scores obtained from the Kolmogorov–Smirnov test and SPSS, the (*) marked line is not normally distributed ($p < .05$), while the other lines are normally distributed ($p > .05$). Therefore, it was accepted to use non-parametric statistical methods in the analysis of the data obtained from SPSS.

SPSS Pretest–Post-test Descriptive Statistics Results of Experimental and Control Groups

Descriptive statistics were used to determine the mean scores of the experimental group before and after application of technology-supported POE activities and the mean scores of control group pre- and post-application of activities in the science coursebook. The results obtained are presented in Table 11.

Experimental and Control Groups SPSS Pretest Findings

Scientific Process Skills Scale consisting of 27 items was applied as a pretest to a total of 40 students in the experimental and control groups. The highest score that can be obtained from the test is 27. The results of the Mann–Whitney *U* test, which was conducted to test the significance of the difference between the experimental and control groups' SPSS pretest scores, are presented in Table 12.

When Table 12 is examined, it is seen that there is a significant difference ($U=123.000$, $z=-2.092$, $p < .05$) between the experimental and control groups. A statistically significant difference was found between the SPSS pretest scores of the experimental and control group students in favor of the experimental group ($p < .05$). According to this result, the scientific process skills of the two groups before the application were different from each other. The effect value size of the SPSS pretest was found to be ($r=.33$). The SPSS pretest shows that the students had a moderate effect on their scientific process skills before the application of the POE technique.

Experimental and Control Groups Post-test SPSS Findings

The results of the Mann–Whitney *U* test, which was conducted to test the significance of the difference between the experimental and control groups' SPSS post-test scores, are presented in Table 13.

Table 12.
The Results of Mann–Whitney U Test Performed to Test the Significance of the Difference Between the Experimental and Control Groups SPSS Pretest Scores

Group	*N*	Mean Rank	Sum of Ranks	*U*	*z*	*p*	*r*
Experimental	20	24.35	487.00	123.000	−2.092	.036*	.33
Control	20	16.65	333.00				

*$p < .05$.

Table 13.
Mann–Whitney U Test Results Used to Test the Significance of the Difference Between the Experimental and Control Groups SPSS Post-test Scores

Group	*N*	Mean Rank	Sum of Ranks	*U*	*z*	*p*	*r*
Experimental	20	24.30	486.00	124.000	−2.066	.039*	.32
Control	20	16.70	334.00				

*$p < .05$.

When Table 13 is examined, it is seen that there is a significant difference between the experimental and control groups ($U=124.000$, $z=-2.066$, $p < .05$). A statistically significant difference was found between the SPSS post-test scores of the experimental and control group students in favor of the experimental group ($p < .05$). According to this result, the post-application scientific process skills of the two groups are different from each other. The effect value size of the SPSS post-test was found to be ($r=.32$). The SPSS post-test shows that the application of the POE technique has a medium effect level on students' scientific process skills.

Pretest–Post-test SPSS Findings

When the descriptive statistics in Table 11 are examined, the Wilcoxon-signed rank test results are presented in Table 14 to determine the significance of this increase in the pretest–post-test mean scores of the students.

When the results obtained from Table 14 are examined, it is seen that there is no significant difference between the pretest–post-test rank averages ($Z=-1.136$, $p > .05$, $r=.17$). When the mean rank and totals of the difference scores are taken into account, it is seen that this observed difference is in favor of the positive ranks, that is, the post-test score. According to these results, it is seen that technology-supported POE activities are effective in scientific process skill levels. However, when the effect size is examined, it has been concluded that the POE activities applied have a low level of effect on the scientific process skill levels.

Discussion, Conclusion and Recommendations

In this research, the effect of the application of technology-supported POE activities developed for the subjects of "photosynthesis and cellular respiration" through distance education on the academic achievement and scientific process skill levels of the students was examined. In this context, the teaching of "photosynthesis and cellular respiration" subjects was carried out with technology-supported POE activities developed by taking into account the achievements of "photosynthesis and cellular respiration" in the 2020–2021 academic year. In the control group, it was carried out with the activities in the eighth-grade science coursebook used in the 2020–2021 academic year in accordance with the science education curriculum.

The answer to the first of the sub-problems of this research, "Is there a significant difference between the academic achievements of the students in the experimental group, in which technology-supported POE activities prepared for the subjects of photosynthesis and cellular respiration were applied via distance education, and the students in the control group, where the activities in the science coursebook were applied via distance education?" was searched. Photosynthesis and Respiration Achievement Test was applied to the experimental and control groups as a pretest and post-test before and after the application of technology-supported POE activities via distance education. The purpose of the pretest is to look at the normality of the distribution of the data and to examine the significance value between the achievements of the groups. Considering the pretest findings, there was a significant difference between the academic achievements of the students in the experimental and control groups. According to the findings, the

Table 14.
Pretest–Post-test SPSS Wilcoxon-Signed Ranks Test Results

Pretest–Post-test	*n*	Mean Rank	Sum of Ranks	*Z*	*p*	*r*
Negative rank	13	12.73	165.50	−1.136	.25	.17
Positive rank	16	16.84	269.50			
Ties	11					

$p < .05$.

achievement levels of the students in the experimental and control groups about "photosynthesis and cellular respiration" are different from each other. That is, the prior knowledge of the experimental and control groups differs from each other. It can be thought that the reason for this situation is due to the fact that the students are educated by different teachers in different branches. The effect size of the PRAT pretest was found to be $r=.31$. The pretest of PRAT shows that students' academic achievement has a moderate effect before POE technique. In the research, technology-supported POE activities were carried out through distance education in the experimental group, and the activities in the science textbook were carried out in the control group through distance education. In the last part of the research, PRAT was applied to both groups as a post-test. After the PRAT was applied as a post-test, the findings were evaluated. When the PRAT post-test scores of the students in the experimental and control groups were examined, it was determined that there was a significant difference between the achievement test post-test scores in favor of the experimental group. In addition, the effect value size of the FSBT post-test was found to be $r=.77$. The post-test of PRAT shows that the application of technology-supported POE technique has a high level of impact on students' academic achievement. According to these findings, it has been determined that technology-supported POE activities applied to the experimental group in the distance education process are more effective in increasing the academic achievements of the students than the activities in the science coursebook applied to the control group. Similarly, Acar-Şeşen and Mutlu (2016), Akgün et al. (2014), Ayvacı and Durmuş (2016), Bilen and Aydoğdu (2010), Bilen and Köse (2012), Durmuş (2014), Egypt (2009), Karamustafaoğlu and Mamlok Naaman (2015), Kearney (2004), Liew and Treagust (1998), Özdemir (2011), Özyılmaz and Hamurcu (2009), White and Gunstone (1992), Yaşar and Baran (2020), and Yavuz and Çelik (2013) presented findings in their research that the POE technique increases the academic achievement of students. Similarly, in the studies conducted by Palmer (1995) and Chew (2008), in which the use of traditional teaching methods and techniques and the use of applications based on the POE technique were compared, it was determined that more successful results were obtained with POE applications.

It can be thought that the reason for the significant difference between the post-test achievement scores of the students in the experimental and control groups may be that the POE technique enables students to benefit from this information at a high level by activating their prior knowledge (Şimşek, 2006). According to Inhelder and Piaget (1958), students' prior knowledge has an important place in learning. Other studies conducted in this context also support the idea that prior knowledge has an effect on increasing students' success (Own, 2005; Thompson & Zamboanga, 2003). The fact that the increase in the achievement post-test scores of the experimental group in this research was higher than the increase in the achievement post-test scores of the control group may be due to the fact that the control group students started the lesson without realizing that their prior knowledge about the concepts was incomplete or incorrect. If prior information is incomplete or incorrect, new information built on this information may also be incorrect (Hewson & Hewson, 1984). In the studies conducted by Liew and Treagust (1995, 1998), the effects of TGA technique on the understanding of science concepts were investigated and it was determined that students' understanding levels of concepts improved.

The answer to the first of the sub-problems of this research, "Is there a significant difference between the scientific process skill levels of the students in the experimental group, in which technology-supported POE activities prepared for the subjects of photosynthesis and cellular respiration were applied via distance education, and the students in the control group, where the activities in the science coursebook were applied via distance education?" was searched. A statistically significant difference in favor of the experimental group was found between the pretest SPSS scores of the experimental and control groups. According to this result, the scientific process skills of the two groups before the application were different from each other. It can be thought that the reason for this situation is due to the fact that the students are educated by different teachers in different branches. The effect value size of the SPSS pretest was found to be ($r=.33$). The SPSS pretest shows that the students had a moderate effect on their scientific process skills before the application of the POE technique. In the last part of the research, SPSS was applied to both groups as a post-test. After the SPSS was applied as a post-test, the results obtained were evaluated. When the results were examined, it was seen that there is an increase in the SPSS scores of both groups. When the SPSS post-test scores of the students in the experimental and control groups were examined, it was determined that there was a significant difference in favor of the experimental group. Finding a significant difference indicates that the technology-supported POE technique is more successful in improving students' scientific process skills. Scientific process skills are defined as the skills that scientists use to do science, such as inferring, classifying, hypothesizing, and experimenting (Rezba et al., 2007). The students in the experimental group used causal processes over the case presented during the prediction stage during the application of the POE technique and determined the variables by establishing hypotheses about the event. After obtaining the data in the observation stage, they evaluated the data in the explanation stage and made operational explanations. Thus, the worksheets used in this process supported the development of students' scientific process skill levels. Although the worksheets used by the control group students were formally suitable for developing their scientific process skills, the content presented for the development of these skills was more limited.

In the literature, there are studies examining the effects of POE technique on students' scientific process skills. Liew (2004) investigated the effects of POE technique on students' scientific process skills and academic achievement, and as a result, it was determined that POE technique made positive contributions to students' scientific process skill levels and academic achievements. In their research, Wu and Tsai (2005) determined that POE technique had positive effects on students' achievement, cognitive structures, and scientific process skills. Similarly, Bilen and Aydoğdu (2010) determined that the POE technique had a positive effect on the development of scientific process skills and had a positive effect on the nature of science, while Karatekin and Öztürk (2012) determined that the POE technique had positive effects on students' academic achievement and scientific process skills. Sağırekmekçi (2016) stated that the POE technique had a significant effect on the scientific process skills of the students, while Kara (2017) stated that the academic achievement and scientific process skills of the students in the experimental group who used the POE technique were positively affected. The findings of this research support the results obtained from these studies. There are other studies in which the POE technique has positive effects on pre-service science teachers' scientific process skills (Bilen, 2009; Russell et al., 2003; Tokur, 2011). In the POE technique, which tries to create an educational environment in which they can develop their scientific process skills by doing and experiencing, students use their prior knowledge of the application to be made by making use of the theoretical information presented to them while writing their predictions. In this context, they produce hypotheses and express their opinions about the variables that affect them. Contrary to these studies, Özdemir (2011) found in his study that while the POE technique had a positive effect on the conceptual achievement of pre-service science teachers, it did not have a significant effect on developing their scientific process skills.

According to the results of the research, it has been determined that the application of technology-supported POE activities through distance education has a positive effect on the academic achievement and scientific process skill levels of the students. The positive increase in the cases after the application reveals that there is a relationship between academic achievement and scientific process skills. This situation supports other research findings in the literature (Akgün et al., 2014; Aktaş & Ceylan, 2016; Bilen, 2009).

Extension and Suggestions for Future Implications

The following suggestions are presented in the light of the results of the technology-supported POE activities on the subject of photosynthesis and cellular respiration regarding the academic achievement and scientific process skill levels of secondary school students:

- Other subjects in the science coursebook can be arranged according to the POE technique and students' conceptual changes and developments can be examined.
- In order to support the quantitative data obtained as a result of the applications, interviews can be held to get the opinions of the students about the process.
- Researches can be planned on determining misconceptions with technology-supported POE technique and its effectiveness in teaching concept.
- Since the subject of "photosynthesis and cellular respiration" is difficult to understand, conceptual change strategies can be used.
- Animations and videos should include content suitable for daily language and human voice. Care should be taken to ensure that these contents are suitable for real life. It is also important for teachers to take precautions against the problems they may encounter by knowing the advantages and disadvantages related to the use of animation and simulation.

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