Necatibey Eğitim Fakültesi Elektronik Fen ve Matematik Eğitimi Dergisi
Cilt 17, Özel Sayı, Ekim 2023, sayfa 285-316. ISSN: 1307-6086
Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education
Vol. 17, Special Issue, October 2023, pp. 285-316. ISSN: 1307-6086

Research Article

Examining the Role and Perceived Importance of Video Experiments on Pre-Service Science Teachers' Understanding of Faraday's Law in Online Learning Environment

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Received : 04.09.2023 Accepted : 22.09.2023
https://doi.org/10.17522/balikesirnef.1355054

Abstract–In this study, it was aimed to reveal the effect of teaching designed using real experiment videos on the development of pre-service science teachers' ideas about Faraday's law of induction and to determine the experiments that pre-service science teachers considered most effective in their understanding of the induction phenomenon. The study was conducted online during the pandemic period with a sample of 52 first-year pre-service science teachers. The predict-observe-explain (POE) learning model was used in the teaching process and semi-structured interviews were conducted with nine pre-service science teachers before and after the teaching. The interview data showed that the pre-service science teachers had many scientifically unacceptable ideas about Faraday's law before the instruction, while these ideas were transformed into scientific truths after the designed instruction. In addition, it was tried to determine the experiment or experiments that pre-service science teachers found most effective in understanding the subject after the instruction. Finally, it was concluded that teaching based on the POE learning model supported by real experiment videos used in online teaching was successful in remedying pre-service science teachers' unacceptable notions about electromagnetic induction and various suggestions were made in this regard.

Key words: POE learning model, online learning, Faraday' s law, physics experiments, pre-service science teachers.

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Introduction

Coronavirus, which unexpectedly affected the whole world, was declared as Covid-19 pandemic by the World Health Organization on March 12, 2020 (WHO, 2020). Thus, many educational institutions worldwide, from preschool to university, have closed their doors (Saavedra, 2020). In most countries, education is provided through distance education platforms (Reimers, 2020). Higher Education Council (HEC) announced all universities to continue education with their distance education resources on the 18th of March, 2020, as in Turkey (YÖK, 2020). Thus, all universities have completed their preparations and switched to distance education in a synchronous or asynchronous manner.

Today, distance education is often associated with the Internet. In fact, much earlier, teaching activities were carried out via radio, mail, or TV (Moore & Kearsley, 2012; Sumner, 2010), and distance education was also used to describe a form of education that is carried out via radio, letter, mail, or TV. Over time, both the definition and the way of application of distance education, which has turned into an online learning environment thanks to developments in technology, have changed (Siemens et al., 2015). Digital transformation is now associated with Industry 4.0 and widely used in the 21st-century world. Therefore, the use of different systems and tools in education has become mandatory due to the Covid-19 pandemic.

Distance learning has many advantages. First of all, it is quite cheap after the initial investment costs are covered. People can receive education from different parts of the world regardless of time and place. Unlike traditional course materials, students can easily adapt multimedia materials to distance education. They can increase or decrease their study hours according to their learning speed (Şahin, 2021).

It is known that distance education, which has entered our lives compulsorily with the pandemic, also has some limitations. Internet connection problems that may occur during the lesson (Korkmaz & Toraman, 2020; Saltan, 2017); lack of interaction between the students and the educators, difficulty in providing feedback to students (LaRose & Whitten, 2000); difficulty in teaching according to the individual interests and abilities of the students (Nart & Altunışık, 2013); not being able to provide skills teaching, lack of student motivation during online learning (Sintema, 2020) are examples of these limitations. Studies on distance education at different age levels during the pandemic process have reported that similar problems are experienced and for these reasons, participation in the courses is low (Başaran et al., 2020; Karademir et al., 2020; Koçoğlu & Tekdal; 2020; Korkmaz & Toraman, 2020; Şahin, 2021; Ünal & Bulunuz, 2020). As a result of these studies, it was seen that alternative methods and techniques are needed to make online education more efficient and to increase students' interest and motivation. On the other hand, instructors need to have some basic technology usage skills to provide online education. Therefore, it is necessary to support the lessons with a number of different teaching materials and techniques to ensure classroom control, student motivation, and an interactive learning environment (Winstead, 2021).

The Predict-Observe-Explain (POE) is a learning model that allows students' motivation and interest to be highly utilized and allows the use of a variety of teaching materials. POE was developed by White and Gunstone (1992), and Pegg (2006) defined POE as the most basic inquiry-based model. In the POE model, the steps are as follows: In the first stage, the prediction; students are presented with a situation, scientific problem, or activities. Students are requested to make predictions with their justifications regarding the possible outcome of the concept or event presented. In the second stage, the observe, students make observations about the initial event and learn to infer a cause-effect relationship for the initial event by taking their observations into account. Observations are repeated when necessary. In the final stage, the explanation stage, students are asked to compare their predictions and observations (Kearney, 2004; White & Gunstone, 1992; Yaşar & Baran, 2020). Many studies have proved that the POE model is beneficial for students learning science (Banawi et al., 2019; Choowong & Worapun, 2021; Hong et al., 2014; Hsiao et al., 2017; Nalkıran & Karamustafaoğlu, 2020; Yang & Chen, 2021). This approach is suggested to be implemented to improve students' conceptual understanding by actively confronting the students with their prior knowledge and to encourage knowledge application as well as construction (Chen et al., 2013; Hsu et al., 2011; Rini, et al., 2019; Zhao et al., 2021). On the other hand, studies show that combining the POE learning model with online learning or digital audio and video learning can help students understand concepts (Akpınar, 2014; Chen, 2020; Hsiao et al., 2017; Yang & Chen, 2021).

Since physics topics involve highly abstract concepts, they should be supported by practical work in which students actively participate in the learning process (El Kharki et al., 2021). Practical work is defined as an indispensable feature in science and physics courses (Abrahams & Millar, 2008; Cai et al. 2021; Gott & Duggan, 1996; Wellington, 1998). Yet in spite of the importance attached to the practical work, it has been reported in various studies that the physics courses are mostly based on mathematical equations and lectures on a theoretical basis by ignoring the basic concepts of the students at the university level (Marrongelle, 2004; Mulhall & Gunstone, 2012; Redish & Gupta, 2009). Considering the claim that practical work strongly influences students' understanding of science concepts (Millar, 2010), it is necessary to investigate the effectiveness of a designed teaching model that is based on the pre-conceptions of the students and includes practical work with teacher demonstrations. It is emphasized that activities that make students active in the lessons, such as experimentation under practical work, will facilitate students' learning and increase their interest and motivation in the lesson (Palmer, 2009). In a similar line of thought, as Chen (2020) reported in his study, it can be argued that the use of teaching approaches that engage students in active learning might increase their interest and motivation towards learning the subject matter in online learning too.

Induction is one of the most difficult abstract topics in physics for students to understand (Guisasola et al., 2004; Maloney et al., 2001; Törnkvist et al., 1993). Studies show that even university students attempt to interpret the formation of induced electromotive force (emf) based on the presence of a magnetic field or based on the direction of the magnetic field lines, without relating it to the flux change (Kocakülah, 1999; Kocakülah, 2002; Loftus, 1996; Thong & Gunstone, 2008; Zuza et al., 2016). Tangible examples and taking note of everyday events that simplify the understanding of induction help to clarify its understanding in students' minds and have a role in motivating students to learn. Examples that can be demonstrated in a classroom environment can be achieved with a couple of mechanisms that can be easily set up. In the classroom environment with different methods of closed circuits, students can be shown that flux change must occur to use Faradays' law $\varepsilon = -N\, d\phi/dt$ and form-induced emf. However, as a result of the transition to distance education with the pandemic, not being able to perform laboratory applications and demonstrations with them, which students will follow with interest and curiosity, appears as a deficiency in their conceptual understanding.

With the introduction of computers into all areas of our lives, the use of virtual laboratory simulations in teaching has increased especially since 2010 (Raman et al., 2022; van Joolingen et al., 2007). There are also studies showing that the use of virtual laboratories has a positive effect on students' conceptual understanding (Lestari & Supahar, 2020; Raman et al., 2022; Taasoobshirazi et al., 2006; Zaturrahmi et al., 2020). However, while there are researchers who advocate the use of virtual laboratories instead of real experiments in students' conceptual understanding (Finkelstein et al., 2005; Klahr et al., 2007), there are also studies showing the benefits of using both applications in a way that supports each other (Anam et al., 2023; Başer & Durmuş, 2010; Brinson, 2015; Jaakkola & Nurmi, 2008; Ronen & Eliahu, 2000; van Joolingen et al., 2007; Zacharia et al., 2008; Zacharia, 2007). On the other hand, Ma and Nickerson (2006) state that the effectiveness of laboratory work depends on how much students believe in the experiments. Similarly, Kocakülah and Kocakülah (2006) conducted interviews with pre-service teachers about the teaching of electromagnetism using simulations and real experimental setups together. The students stated that simulations were not as convincing as real experiments, learning would not be permanent in a lesson based only on simulations, and simulations could be used for reinforcement at the end of the lesson.

For the above reasons, in this study, it was decided to use real experiment videos prepared by the instructor in distance education in order to be more interactive with the pre-service science teachers and to increase the credibility of the experiments instead of ready-made simulations that can be easily accessed on the internet.

In this study, a teaching model based on a POE has been designed for the pre-service science teachers in an online classroom environment by taking into account the pre-conceptions of the pre-service science teachers and supporting with different real experiment videos. Therefore, this study aims to reveal the impact of designed teaching using different experiment videos on the development of pre-service science teachers' ideas about Faraday's law of induction and to determine the experiments that pre-service science teachers consider the most effective in their understanding of the induction phenomenon.

Method

Research Design

A study with one-group pretest-posttest weak-experimental design (Fraenkel et al., 2012) was conducted in a university introductory physics course to evaluate the effectiveness of the real experiment videos during teaching Faraday's law of induction. The study was conducted during the Covid-19 period and in the 2021-2022 academic year, and there was only one physics class during the study period.

Participants

This study was carried out with 52 first-year pre-service science teachers, attending the faculty of education at a state university in the western part of Turkey, ranging in age from 19 to 21. The faculty where the researcher works was selected for the purposes of the purposive sampling method. The faculty has a good reputation in training and has trained pre-service teachers for over a century.

Data Collection

The data collection tool used in the study to reveal the effectiveness of the instruction was semi-structured interviews. Nine pre-service science teachers who were interviewed in the study were selected on a voluntary basis and among the pre-service science teachers who did not have internet connection problems in the class. Before and after instruction, those nine pre-service science teachers were each online interviewed for between 30 and 45 minutes. Five of the pre-service science teachers were female and four were male. During the interviews, the researcher conducted the experiments online from the laboratory using the experimental setups prepared in advance. The purpose of designing the interviews in a semi-structured way was to be able to ask different questions to the pre-service science teachers by making the desired changes in the experimental setup when necessary and thus to obtain more detailed data. The data obtained from the interviews were transcribed and analyzed descriptively and presented in the findings section in relation to the pre- and post-instruction findings.

In order to determine the experiment that the pre-service science teachers found most effective at the end of the instruction, a questionnaire was used as another data collection tool. At this stage, data were collected through a questionnaire sent via Microsoft Forms. In the questionnaire, the pre-service science teachers were asked to write which experiment or experiments were effective in their understanding of the subject from the experiments used in the course and to write this with the justification. The data obtained were presented by frequency analysis.

Teaching Process

In the university where this study was conducted, Microsoft Teams software is used as a distance education platform. Therefore, all of the lessons and interviews were conducted through this application. In addition, Microsoft Forms application was also used from time to time for the pre-service teachers to respond to the questions asked during the course.

The teaching period lasted 6 course hours (each course hour is 90 minutes) and the devised teaching plan was administered in the 'Physics II: Electricity and Magnetism' course conducted by the researcher.

The teaching process consists of three stages. Before starting to teach the topic, the short life story of Michael Faraday from the documentary entitled Einstein's Big Idea was shown to attract pre-service science teachers' attention and arouse curiosity. Then, a short discussion was held with the pre-service science teachers on the importance of Faraday's experiments, which both activated the pre-service science teachers' prior knowledge and guided the instructor to determine the pre-service science teachers' level of knowledge. This part was completed in one class hour.

Table1 Experiments used during teaching and their specific objectives

Lesson Number	Experiment Number	Experiment Name	Purpose
Lesson II	1	Deflection of the galvanometer pointer	To demonstrate the formation of the induced emf that is indicated by the deflection of a galvanometer pointer by means of the changing magnetic effect of a bar magnet which is moved towards and away from a coil whose ends are attached to a galvanometer.
	2	A coil connected to the direct current source by a switch	To understand the formation of an induction current with a direct current and to demonstrate that a conductor carrying a current is also the source of a magnetic field.
Lesson III	3	Lighting up a led bulb	To comprehend the formation of the induced current with an alternating current source.
	4	Lighting up a torch bulb	To observe whether an induction current is generated by direct current and alternating current sources.
Lesson IV	5	Jumping aluminum ring	Same purpose as experiment 4.
	6	Split aluminum ring	To discuss the closed path in which the induction current flows.
Lesson V	7	Aluminum pipe experiment	Same purpose as experiment 1.

In the second stage, lessons were taught in accordance with the POE model. In the first phase of the instructional model, the online video demonstration experiments to be carried out were presented to the pre-service science teachers respectively, and they were asked to estimate the outcome of each experiment and explain the reason for their estimation. Pre-service science teachers were asked to write their predictions through Microsoft Forms application. In the second phase, demonstration experiments videos were watched. At this stage, each experiment was repeated several times so that all pre-service science teachers could see the experiment and fully understand the event. In the third phase, pre-service science teachers were asked to compare their predictions and observations for each experiment, and the results were discussed in the class respectively. Table 1 summarizes the experiments carried out in the teaching process. All videos of the experiments used during the teaching process were shot by the instructor and each detail was carefully explained to the pre-service science teachers.

In the third stage of the teaching, a discussion was held in the classroom about the possible applications of electromagnetic induction in daily life. The working principles of tools such as electric generators, transformer systems, electric guitars, and induction furnaces were discussed with the pre-service science teachers. Then, to show the pre-service science teachers how the induction furnace works, the device in Figure 1 was set up in the laboratory by the researcher and the video of the device was recorded and shown to the pre-service science teachers during the lesson. In this way, the pre-service science teachers observed the change in the temperature of the water in the pipe and discussed how Faraday's Law applies to the situation in this setup.

Figure 1 The experimental set-up for induction cooker

Introducing Experiments

Experiment 1

The change in the magnetic flux passing through the cross-sectional area of the coil is explained to pre-service science teachers based on the change in the position of the magnet in relation to the coil, and the amount of deflection of the galvanometer pointer can be observed using two coils with N=12,000 and N=1,200 (where N equals the number of turns in the coil). With such an implementation, pre-service science teachers can see that the induced emf is directly proportional to the number of turns in the coil.

Experiment 2

A second coil, which was located beside the first coil whose ends were attached to the galvanometer directly, was connected in series to the direct current output of a power supply and a switch (see Fig. 2). Direct current was supplied to the coil by the power supply, and the flux change was performed by opening and closing the switch. Then, the deflection of the galvanometer pointer attached to the other coil indicated the existence of an induced current.

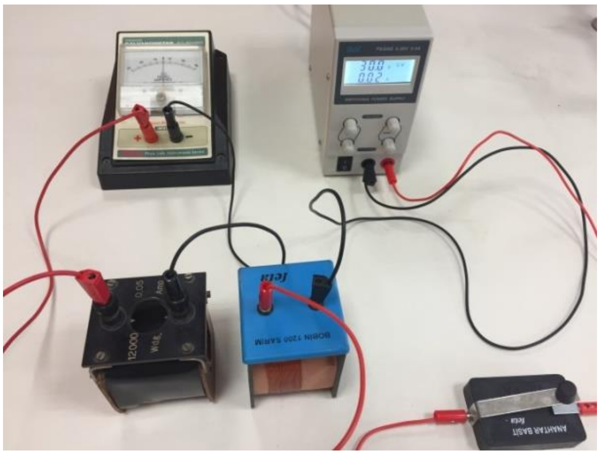

Figure 2 The experimental set-up for experiment 2

Experiment 3

A coil with 300 turns was first attached to the alternating current from the power supply. A LED diode was attached to the ends of the other coil with 12,000 turns and this coil was located in close proximity to the other coil; the two coils did not touch, and their axes coincided. When an alternating 10 V source is applied to the coil attached to the power supply, it will be observed that the diode attached to the other coil will light up as can be seen in Figure 3.

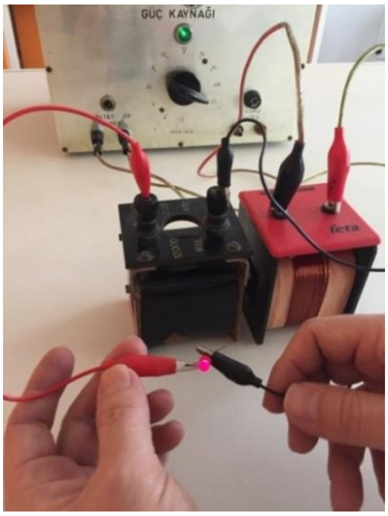

Figure 3 The experimental set-up for experiment 3

Experiment 4

The second coil with 1200 turns and a torch bulb connected is placed onto a coil with 300 turns around an iron bar located on a tripod. The second coil with 1200 turns and a bulb connected to its ends is held slightly above the lower coil with 300 turns connected to the power supply providing alternating current. In this way, when an alternating 10 V supply is initially applied to the first (lower) coil, the bulb is observed to light up. When the upper coil is moved vertically, the brightness of the bulb changes. Using the same mechanism, the experiment can be continued by applying direct current to the coil attached to the power supply, and a second coil is placed so that its axis coincides with the first coil (see Fig. 4).

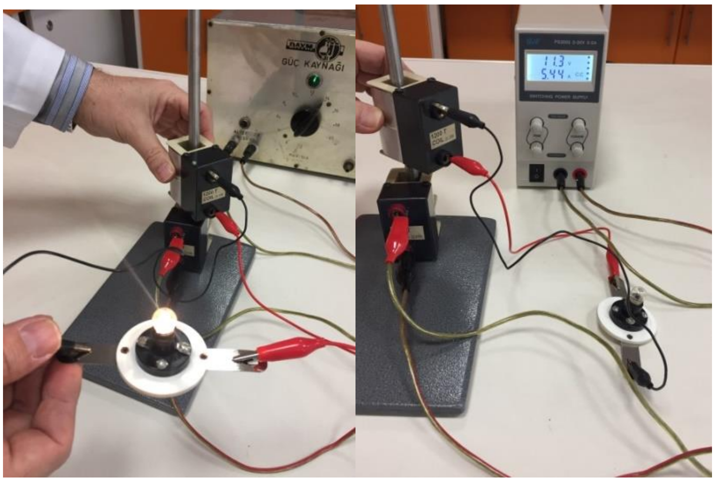

Figure 4 Pictures of the two experimental set-ups which were used in the experiment 4

Experiment 5

An aluminum ring is placed onto a coil with 300 turns around an iron bar located on a tripod. When an alternating 10 V source was applied to the coil, it was observed that the aluminum ring hung at a certain height above the coil. Using the same mechanism, the experiment can be continued by applying direct current to the coil attached to the power supply and adding an aluminum ring so that its axis coincides with the coil connected to the power supply, as illustrated in Figure 5.

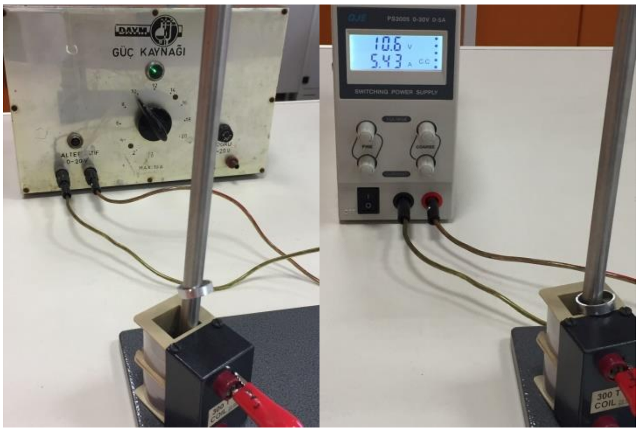

Figure 5 Pictures of the two experimental set-ups which were used in the experiment 5

Experiment 6

With the continuous ring on top of the coil attached to the power supply, a split ring can be placed beneath the continuous ring on the coil at this stage. When the alternating power supply is turned on, it was observed that only the continuous ring jumps on the coil.

Experiment 7

The presence of an induced current can be demonstrated using an aluminum pipe with a diameter of about 3.50 cm, a length of 80 cm, and a cylindrical permanent neodymium magnet with a mass of approximately 50 g instead of a coil. The aluminum pipe is placed vertically on the table and the neodymium magnet is allowed to drop under gravity from one meter above the table-top inside and outside the pipe, and the time when it hits the ground is measured. Additionally, a 50 g iron mass that does not show any magnetic characteristics was dropped inside and outside the same aluminum pipe at a height of one meter and the time to fall was measured. Therefore, the pre-service science teachers were provided with a comparison between the time to fall for both the magnet and the iron mass dropped from the same height.

Findings and Discussions

In this study, which aims to gain in-depth information about the demonstration experiments shown in online lectures, the findings related to the pre- and post-teaching interviews with the pre-service science teachers and the findings of the online survey are presented in this section. The findings are given in two sub-headings as pre-teaching and post-teaching findings below.

Pre-teaching Findings

Firstly, experiment 1 was carried out and when the pre-service science teachers were asked why the galvanometer needle was deflected by the movement of the magnet, all the interviewed pre-service science teachers thought that the coil was affected due to the magnetic field of the magnet. When asked how the coil is affected by the magnetic field, they mainly stated that the coil produced a current and deflected the needle. However, when further probed why the needle deflected when the magnet moved only, all pre-service science teachers left the question unanswered. For instance, pre-service teacher 1 explained that ''*when the magnet moves, the magnetic field is formed due to the action-reaction, then the movement of the magnet is necessary*''. On the other hand, pre-service teacher 2 reasoned that ''*there is a magnetic field around the magnet. It is like we can think of a ball on the ends of a magnet. When we thrust the magnet into the coil, we can think that the ball is squeezed, which causes pressure inside the coil and forms something. This formation produces tension on the wires of the coil and deflects the needle*''. Moreover, pre-service teacher 4 interpreted the deflection of the needle during the movement of the magnet using energy transformation with a correct approach. She responded that ''*it is related to the motion of the magnet. Do we increase its kinetic energy? Kinetic energy may be transformed into electrical energy. Since the kinetic energy is zero when the magnet is stopped, the current is not produced*''. None of the pre-service science teachers has yet used the concept of magnetic flux in the interviews.

In the next step of the experiments, experiment 2 was made and the pre-service science teachers were asked why the needle deflected when the switch was only turned on or off. All of the pre-service science teachers responded that the coil would produce a magnetic field when direct current is applied to the coil and that field was thought to have an influence on by creating a current in the other coil as in the previous experiment. Additionally, the pre-service science teachers tried to explain this event by making reference to the direct current. Below, part of the discussion with pre-service teacher 7 on this issue during the interview is presented.

Pre-service science teacher 7: *That means when we first turn off the switch at the direct current, the magnetic field is formed but after a while, it is not produced.*

Researcher: *Do you think that the magnetic fields created by direct current and alternating current are different*?

Pre-service science teacher 7: *I think it is very different*.

Researcher: *How is it different?*

Pre-service science teacher 7: *I wonder whether the current does not have enough power. It (current) may accept the coil as a resistance as long as the switch is turned on for a long time. That is why the needle is not deflected.*

Researcher: *So what would we see if we connected this coil to an alternating current supply?*

Pre-service science teacher 7: *I think the current always would reach a value and remain constant*.

Researcher*: Let's try it*. (The coil is connected to the alternating current supply). *What happened?*

Pre-service science teacher 7: *The needle is vibrating at the zero point*.

Researcher: *Is it what you think it is?*

Pre-service science teacher 7: *No, I was saying that the needle rotates up to a point and stops there. I am surprised now*.

Pre-service science teacher 7 knows that alternating current and direct current are different types of currents but cannot explain the situation in this experiment. Because, like other pre-service teachers, he focuses only on the formation of the magnetic field and cannot provide an idea about the concept of magnetic flux. Therefore, he tried to answer the question by considering that the magnetic fields of the two currents would be different. Similarly, pre-service science teachers 6, 9, and 2 put forward the idea that a time-varying current should exist and responded as follows: ‘‘*The alternating current provides discontinuous energy while the direct current gives continuous energy. Here, we turn the switch on and off, so we will create a discrete current, i.e. moving the magnet around the coil*’’.

In the next part of the interview, experiment 3 was presented to the pre-service science teachers and the reason for how the diode lighted up was asked. The pre-service science teachers indicated in a similar manner to the previous explanations that a current would occur due to the interaction of the magnetic field with the coil to which the lamp was connected as long as the magnetic field was formed. Only four pre-service science teachers emphasized the need for alternating current and stated that a time-varying current could light up the diode. However, those pre-service teachers did not put any emphasis on flux change.

After talking about two set-ups related to direct current and alternating current, experiment 4 was performed to reveal what the pre-service science teachers think about a new situation. The pre-service science teachers suggested again that the current was formed in the upper coil only due to the magnetic field of the lower coil. When asked if the iron bar has an influence on the formation of the current, pre-service science teacher 1 and pre-service science teacher 6 explained that the bar had no function on the creation of current because the coils were not touching the bar either. However, the rest of the pre-service science teachers interviewed asserted that the rod would strengthen the magnetic field due to the fact that it was conductive. For example, pre-service science teacher 8 reasoned as follows: ''*Iron rod conducts the magnetic field. Maybe the bulb would not light up if there was not a rod. It basically increases the strength of the magnetic field*.'' The pre-service science teachers were asked whether the bulb would light up when a direct current was applied to the lower coil. Five of the pre-service teachers stated that the bulb would be less bright or might not light up. When asked for the reason for their arguments, they suggested that ''*the energy of the direct current is lower than the alternating current*" or ''*it was due to magnetic field which was not being created*''. The other four of the pre-service science teachers interviewed stated that the bulb would light up at first and then fade. Pre-service science teacher 3, for instance, explained that ''*the bulb goes on and then off in the direct current. Because the direct current is constant, there is no change. The magnetic field needs to be formed continuously. I thought the magnetic fields at the top and bottom coils would damp each other*''.

The interviews continued with experiment 5 involving the aluminum ring experiment. The pre-service science teachers argued that the magnetic field emitted from the coil enabled the ring to be rised above the coil by acting on the ring but they could not make a correct explanation. They also stated that the ring was affected by the magnetic field because it was made of aluminum, and if the ring was another kind of metal (such as iron), it would have been attracted by the coil. When the pre-service science teachers were asked to predict the temperature of the ring, they stated that the ring would be hot and pre-service science teachers 3, 4, and 5 commented that there might be a current transition between the ring and the iron bar, while pre-service science teachers 1, 6 and 7 stated that the magnetic field might be passing through the ring.

The same experiment was made with a split ring. Pre-service science teachers 1 and 7 indicated that the magnetic field could not pass over the ring because of the slit in the ring and the ring did not rise by making reference to their earlier ideas in the interview. The other pre-service science teachers, who thought that the ring should jump upwards, stated that due to the magnetic field of the coil, it should jump slightly less than the continuous ring. However, when the experiment was performed and the discontinuous ring did not jump, for example, Pre-service science teacher 5 responded intuitively that ‘‘*the magnetic field could not pass through the slit and was unable to push the ring upwards because the ring was split*’’. Moreover, pre-service science teacher 4 made an inference on the basis of his observations in the previous ring experiment and responded as follows: ‘‘*So, the ring really had a current beforehand. Because the ring is split, there is no current on it and it does not jump then*’’.

Finally, the aluminum pipe experiment was performed and it was asked why the magnet fell late when it was allowed to drop under gravity inside the pipe. The pre-service science teachers stated that the magnet fell slowly due to the magnet being pulled slightly by the aluminum pipe. However, when the magnet was brought closer to the pipe later, they saw that there was no pull as they thought, and they were even more surprised. In particular, when pre-service science teachers watched the movement of the magnet from the top of the pipe, they understood that their assumptions completely lost their basis. Pre-service science teacher 6 explained his observation in the following way: ‘‘*Magnetic field lines are in the form of rings and the magnet goes down without hitting the walls of the pipe. The magnet is under the influence of its own field and it does not touch the pipe. First, I thought the magnet was slow because it touched the pipe's wall but that was not the case*’’. Pre-service science teacher 8 insisted on the idea of the push-pull effect and made the explanations in the transcript below.

Researcher: *What is the source of pushing or pulling?*

Pre-service science teacher 8: *Opposite charges create a force between the pipe and the magnet. I thought the same charges would push each other and the same rule works out here. Like the poles of the magnet and electric charges.*

Researcher: *Where do charges exist on the aluminum pipe?*

Pre-service science teacher 8: *Can not be scattered all over the pipe? Because the pipe is electrically conductive...*

Researcher: *So?*

Pre-service science teacher 8: *Perhaps, the magnet is interacting with the charges inside the pipe and slowing itself down.*

Although Pre-service science teacher 8 commented that charges could exist on the pipe, this idea is entirely based on the pre-service science teacher's alternative idea of mixing the electrical charges with magnetic poles. Therefore, the pre-service science teacher could not propose a correct explanation.

It can be seen from the pre-teaching interview data outlined above that the pre-service science teachers could not go beyond just explaining the questions related to the induction event depending on the magnetic field concept. Although some pre-service science teachers put forward correct ideas, they did not make any explanations about the change of the magnetic flux which is the key concept in answering the questions. The basic problem for many pre-service science teachers is the ability to interpret whether the flux passing through the cross-sectional area of the coil or the ring changes with time. Therefore, the concepts of flux and flux change have been tried to be addressed with all dimensions during the teaching process.

Post-teaching Findings

In the interviews conducted with the pre-service science teachers after the instruction, it was found that the pre-service science teachers abandoned their old ideas and they explained the events presented to them by focusing on flux change. The pre-service science teachers were able to express that not only the magnetic field would be sufficient when responding to the questions in the interviews, but also that the coils used in the experiments behaved differently when connected to the direct and the alternating current sources. The pre-service science teachers, who had difficulty in making explanations especially when direct and alternating currents were applied to the coil attached to the power supply before the instruction, could easily use scientifically correct arguments after the instruction. For example, the ideas presented by pre-service teacher 7 regarding the direct current in the interview transcript given above have changed as follows.

Researcher: *Why does the galvanometer pointer move when direct current is supplied to the coil by the power supply and the switch is turned on and off?*

Pre-service science teacher 7: *Direct current comes from the power supply. There must be a flux change for the induction current to occur. We cannot create such a flux change in* *direct current. We put the switch here and produce discontinuous currents, which in turn make the induction current in the other coil by changing the flux. Thus, the pointer is deflected.*

Researcher: (Experiment 3 is performed) *Well, what happens in the LED connected circuit that we provide alternating current?*

Pre-service science teacher 7: *Here, we are able to create the flux change directly by means of the alternating current, so the LED is lit up by the induction current produced.*

After the instruction, the change of the ideas of the pre-service science teachers towards the scientifically correct notions shows that the teaching process enriched with different experimental setups was successful. Based on this result, pre-service science teachers were asked to comment about their lessons and experiments at the end of the interviews. The pre-service science teachers stated that this way of designing a teaching sequence on Faraday's Law was very effective and it was also important to see experiments in the order given during instruction. Pre-service science teachers 4 explained his views as follows: ''*I have easily grasped such an abstract event. In the pre-interview, I was just explaining the questions using the magnetic field. But I have actually seen that the concept of flux is important. I think if the first experiment with the magnet is well understood, the other experiments are easier to understand. I am most interested in the bulb experiment and the aluminum pipe experiment*''.

Pre-service science teacher 2 expressed the effectiveness of the experiments as follows: ''*If we had not watched the experiments, no one in the class would understand the events here. The experiments were both interesting and increased our curiosity about the topic*''. When asked which experiment was more effective in understanding the subject, she pointed out experiment four and explained the reason as follows: ''*This experiment shows how the alternating current, which constantly changes the flux, lights up the bulb and it also raises the reason why the brightness of the bulb changes when it is moved closer and farther to the lower coil. It also teaches the effect of the iron rod. It provides multiple things at the same time. I think it contains a summary of other experiments. I think it is more effective than the rest of the experiments. In addition, lighting up the bulb convinces me that the current passes through the coil to which the bulb is connected*''. For similar reasons, pre-service science teachers 1, 5, and 8 who were interviewed stated that the fourth experiment was effective in comprehending the induction phenomenon.

Pre-service science teachers 3 and 6 stated that in their pre-teaching interviews, they had difficulty especially because they had incorrect information about alternating current and direct current, but they could now explain the formation of induction current even in different situations. Moreover, Pre-service science teacher 6 expressed that all experiments completed each other in understanding the entire phenomenon of electromagnetic induction and emphasized that the aluminum pipe experiment impressed him very much.

Pre-service science teacher 7, on the other hand, indicated that the aluminum ring experiment, which is difficult to comprehend, plays a key role in the transition to different situations after being grasped. He clarifies this view by explaining that ‘‘*when the difference between alternating and direct currents is known, the formation of the induced current can be better understood with two current types in the aluminum ring experiment*’’.

When Table 2 is examined, the pre-service science teachers have found all of the experiments done reasonably effective. The experiment in the first place was experiment 4 in which the pre-service science teachers observed the light bulb burning as a result of the flux change in a concrete way. In addition, they stated that it is quite interesting and explanatory that the induced current does not occur when direct current is applied instead of alternating current. The second popular experiment is experiment 1, which is considered the first to be observed among 18 pre-service science teachers and is regarded as the main experiment. This experiment is in fact the first experiment of Faraday in 1831 to show the phenomenon of electromagnetic induction (Wikipedia, 2016). In this experiment, the formation of the induced current is indicated by the deflection of a galvanometer pointer when a bar magnet moves towards and away from a coil whose ends are attached to a galvanometer. Here, the magnet is the source of the magnetic field, and the intensity of the magnetic field passing through the plane of the coil changes in time to cause a change in the flux value according to the equation $\phi=B.A.\cos\alpha$.

Table 2 Pre-service science teachers' answers to the question ‘which experiment was the most effective in online learning class?’

Experiment no	Number of pre-service science teachers (n=52*)	Types of pre-service science teachers' justifications
4	23	• It was possible to see whether the induction current occurred or not with direct and alternating current sources in the same experiment • Observing that the bulb was lit up without any power supply as a result of the change in flux caused us to believe that the current was

		formed and led to permanent learning
1	18	• Because it is easy to see flux change and pointer's direction of deflection by using a magnet.
5 & 6	13	• Such an experiment that gives you the opportunity to test multiple variables at the same time. • The function of the iron rod, the presence of the aluminum ring, what raises the ring, why the discontinuous ring does not rise and the alternating-direct current separation are all questionable.
7	11	• It is a magic demonstration and very interesting. All information is combined in this experiment. • From the early to the final stages of the experiment, versatile thinking is enhanced and encouraged.
2	7	• Someone can easily comprehend how the induced current is formed using the direct current. • Understanding that there must be a change in flux is revealed by this experiment.
3	4	• This experiment looked different because we used LEDs. Also, the fact that we used AC current here after the previous experiment had a significant impact.

*Some pre-service science teachers have commented on more than one experiment.

On the other hand, the pre-service science teachers, who preferred experiments 5, 6, and 7 in which aluminum ring and aluminum pipe were used respectively, emphasized that they did not encounter such set-ups before. Those experimental demonstrations were found to require high-level thinking skills and the ability to question more than one event at the same time. Moreover, data analyses show that the reasons for choosing the most effective experiments for both the whole class and interviewed pre-service science teachers were similar to each other.

Conclusions and Suggestions

In this study, an online teaching application using POE learning model and real classroom experiments was implemented to support the conceptual understanding of electromagnetic induction through distance learning. There were many situations in which pre-service science teachers had difficulty explaining conceptually before the instruction. After the instruction, on the other hand, the change of the ideas of the pre-service science teachers towards the scientifically correct notions shows that the teaching process enriched with different experimental setups was successful. This result of the study was consistent with the literature. There are many studies in the literature showing that the POE is an effective learning model (Fuadi et al., 2020; Harman & Yenikalayci, 2022; Nalkiran & Karamustafaoğlu, 2020; Tahir et al., 2020; Tereci et al., 2018; Yulianti et al., 2020). On the other hand, there are also studies showing that the use of the POE learning model in distance education or computer-assisted instruction positively affects students' conceptual understanding and achievement (Alfiyanti et al., 2020; Astiti et al., 2020; Yang et al., 2021; Yaşar & Baran, 2020). In this study, in support of the literature, it was observed that the courses designed according to POE model in distance education helped pre-service science teachers to understand the subject better. Unlike the literature, in this study, a teaching application in which the real experiment videos prepared by the instructor and the POE model were handled together. It is thought that this study will contribute to the literature in this respect. Therefore, it can be suggested that the effect of real experiment videos through distance education should be investigated comparatively in different subjects and fields.

This research involves the teaching of electromagnetic induction in physics. The concept of magnetic flux in this subject can be expressed as a difficult concept that students tend to confuse with the concept of magnetic field. In the interviews conducted at the beginning of the study, the basic problem for many students is the ability to interpret whether the flux passing through the cross-sectional area of the conductor changes with time. For this reason, in the pre-interviews with the pre-service science teachers, the formation of the induced current was tried to be explained by the magnetic field. Similarly, it is stated in different studies that students experience the same difficulties (Albe et al., 2001; Guisasola et al., 2013; Mauk & Hingley, 2005; Thong & Gunstone, 2008; Zuza et al., 2016).

During the pre-teaching interviews, it was observed that only a few of the pre-service science teachers were able to correctly interpret the results of the experiments they encountered. The pre-service science teachers' erroneous explanations were dominated by the ideas that '*two objects act in the form of action-reaction forces*' or that force or current flows from the iron rod to the ring '*just like the flow of water*' as in the aluminum ring experiment. Similar ideas were also found in the studies of Loftus (1996), who investigated how the ideas of secondary school students aged between 14-18 years changed with age while interpreting the electromagnetic induction phenomenon, and Kocakülah (2003), who investigated the change in conceptual understanding of Faraday's Law between first and last year university students.

Before the instruction, the difficulty pre-service science teachers encountered in recognizing the causes of magnetic flux change caused them to be unable to explain how the induced current would be formed during the experiments with alternating or direct current. Although some pre-service science teachers knew that the two types of current have different properties, they could not fully explain their effects in the experiments and could not predict whether the induced current would be formed especially when the alternating and direct current was used. Pre-service science teachers were asked to interpret the situations they observed using AC and DC currents in experiments 2, 3, 4, and 5. It was observed that some pre-service science teachers stated that '*direct current would not create a magnetic field*' or '*it would have no effect because it has a lower energy*'. To the best of our knowledge, this finding has not been observed in any previous study and is a result that emerged for the first time in this study. Although the pre-service science teachers knew that electric current has a magnetic effect, they could not explain why the lamp does not light or the ring does not move when DC is used, based on the flux change. In the interviews conducted after the instruction, it is observed that they have explained the situations they encounter in the light of the flux change. Additionally, they were able to consider the difference of the current type in generating the induced current after teaching.

The second aim of the study was to determine the pre-service science teachers' opinions about the real video experiments used during teaching. The first choice of pre-service science teachers on the shown videos is the experiment 4 in which a torch bulb has been used to generate an induction current by direct and alternating current sources. Then comes experiment 1 in which a galvanometer and a magnet have been used. The reasons for selecting these experiments also coincide with the purposes of conducting experiments during teaching, which is an important result of the effectiveness of the teaching process.

Throughout the research, some limitations were encountered in both the teaching process and the data collection process. In particular, the sudden transition to the distance education process due to the pandemic, the fact that some students had problems with internet connections and participated in the lessons via mobile phones because they did not have computers caused difficulties in communication. For these reasons, the data collection process was carried out with a single method by interviewing only a certain number of pre-service science teachers, and the conceptual understanding levels of the whole class could not be determined. During the lessons, written communication was made with pre-service science teachers who did not have microphones, which sometimes caused the lessons to be prolonged. Since similar problems are among the general limitations of distance education (Korkmaz & Toraman, 2020; LaRose & Whitten, 2000), the interviewed pre-service science teachers were selected among the volunteer pre-service science teachers who had no connection problems, and the semi-structured interview method was preferred in order to obtain detailed data during the interviews. Thus, researchers who want to conduct a study based on distance education can be advised to be prepared in advance to solve technical problems.

The results of the study revealed that even in the distance education, the teaching of physics subjects can be efficient with a teaching process in which students are active and abstract concepts are made concrete through different experiments. Therefore, it is recommended that teachers should conduct experiments and make students active in physics lessons under any circumstances. In addition, in cases where it is not possible to conduct experiments, it is thought that the use of different simulations and daily life activities on the internet will contribute to students' understanding of physics topics.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

No conflict of interest.

Funding

None.

CRediT author statement

The study was single authored and the whole process was carried out by the corresponding author.

Research involving Human Participants and/or Animals

The study involves human participants. Ethics committee permission was obtained from Balıkesir University, Science and Engineering Sciences Ethics Committee.

Fen Bilgisi Öğretmen Adaylarının Faraday Yasasını Anlamalarında Video Deneylerin Rolünün ve Algılanan Öneminin Çevrimiçi Öğrenme Ortamında İncelenmesi

Özet:

Bu çalışmada, gerçek deney videoları kullanılarak tasarlanan öğretimin fen bilgisi öğretmen adaylarının Faraday' ın indüksiyon yasası hakkındaki fikirlerinin gelişimi üzerindeki etkisini ortaya koymak ve öğretmen adaylarının indüksiyon olgusunu anlamalarında en etkili gördükleri deneyleri belirlemek amaçlanmıştır. Araştırma pandemi döneminde online olarak ve 52 birinci sınıf fen bilgisi öğretmen adayından oluşan bir örneklem ile yürütülmüştür. Öğretim sürecinde tahmin-gözlem-açıklama (TGA) öğrenme modeli kullanılmış ve öğretim öncesinde ve sonrasında dokuz öğretmen adayı ile yarı yapılandırılmış görüşmeler gerçekleştirilmiştir. Görüşme verileri, fen bilgisi öğretmen adaylarının öğretim öncesinde Faraday yasası hakkında birçok bilimsel olarak kabul edilemez fikre sahip olduğunu gösterirken tasarlanan öğretim sonrasında bu fikirlerin bilimsel doğrulara dönüştüğünü ortaya koymaktadır. Ayrıca, öğretimden sonra öğretmen adaylarının konuyu anlamalarında en etkili buldukları deney ya da deneyler belirlenmeye çalışılmıştır. Son olarak, online öğretimde kullanılan gerçek deney videoları ile desteklenen TGA modeline dayalı öğretimin başarılı olduğu sonucuna ulaşılmış ve bu konuda çeşitli önerilerde bulunulmuştur.

Anahtar kelimeler: TGA öğrenme modeli, uzaktan eğitim, Faraday yasası, fizik deneyleri, fen bilgisi öğretmen adayları

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