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THE EFFECT OF PROBLEM-BASED LEARNING ON PRE-SERVICE PRIMARY SCHOOL TEACHERS' CONCEPTUAL UNDERSTANDING AND MISCONCEPTIONS

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Abstract

The aim of this research is to investigate the effect of problem-based learning on misconceptions and conceptual understanding regarding simple electric circuits. Participants are 54 pre-service primary school teachers enrolled on the *Basic Science in Elementary School* course at a state university. The research employs a nonequivalent control group model. The activity sheets containing problem-based scenarios prepared by the researcher were used in the experimental group. In the control group, the lecture-based learning supported by problem solving, question-answer, discussion activities and demonstration experiments was used. Data were gathered by three-tier Simple Electric Circuit Diagnostic Test consisting of 12 questions developed by Peşman (2005). The research revealed that problem-based learning is more effective in improving conceptual understanding and overcoming misconceptions than lecture-based learning.

Keywords: Problem-based learning, conceptual understanding, misconceptions, simple electric circuit, pre-service primary school teachers.

INTRODUCTION

In modern education systems, it is aimed to train individuals who can acquire scientific knowledge and concepts, and integrate these into the solutions of problem situations. Learning environments are of great importance in raising individuals with these qualities. This requires learning environments that allow learners to construct and internalize scientific knowledge based on their own prior knowledge. Learners develop some knowledge and explanations about the natural world from formal or informal learning environments based on their experiences (Soeharto, Csapó, Sarimanah, Dewi, & Sabri, 2019). However, these pre-knowledge and concepts do not always correspond to accurate scientific explanations (Duit & Treagust, 2003). The literature shows that the learners have some non-scientific concepts and explanations in various subject fields of science, such as electric circuits (Engelhardt & Beichner, 2004; Küçüközer & Kocakülah, 2007; Peşman & Eryılmaz, 2010; Tahir, Nasri, & Halim, 2020), force and motion (Anggoro, Widodo, Suhandi, & Treagust, 2019; Fadaei & Mora, 2015; Narjaikaew, 2013; Nie, Xiao, Fritchman, Liu, Han, Xiong, & Bao, 2019), chemical bonding (Fadillah & Salirawati, 2018; Fahmi & Irhasyuarna, 2017), acids and bases (Mubarokah, Mulyani, & Indriyanti, 2018), photosynthesis (Haslam & Treagust, 1987; Kırılmazkaya & Kırbağ Zengin, 2016), heat and temperature (Alwan, 2011; Suliyanah, Putri, & Rohmawati, 2018). These non-scientific concepts and explanations pose great obstacles to the conceptual understanding, and it is important to reduce their effect to achieve the determined learning goals. However, scientifically reconstructing these concepts is not always an easy process. The required conceptual change is expressed as the process of repairing the misconceptions to allow a deeper conceptual understanding (Chi & Roscoe, 2002). When considered from this point of view, identifying and correcting the misconceptions is the basis for learners to construct scientific knowledge and concepts. The lecture method is ineffective for this task (Desstya, Prasetyo, Suyanta, Susila, & Irwanto, 2019), and it is necessary to apply appropriate teaching strategies (Widarti, Permanasari, & Mulyani, 2017). For this, learning environments and approaches that give opportunities conceptual change to the learners are needed. It can be said that problem-based learning (PBL) will allow learners to understand if their concepts are correct, and to correct them if not. At the same time, it is thought that the PBL will help the learners to provide conceptual understanding by constructing the conceptual structure of the knowledge in the subject field within the scope of scientific methods. In the following sections, there is a discussion on why and how PBL has these effects.

Theoretical Background

A conceptual understanding becomes meaningful when conceptual knowledge is used in the process of discovering and explaining new situations, beyond knowing the facts and conceptual labels (Roth, 1990). For this reason, there is a need for educational approaches that allow the concepts to be structured beyond memorization and to be interpreted by transferring them to different situations. Considered in a theoretical context, it can be said that cognitive theories are among the leading theories that play a role in concept formation and conceptual understanding. Cognitive theories place great emphasis on learners processing information (Schunk, 2012). Cognitive psychologists who research the mental processes in the learning process argue that prior knowledge has a critical role in the learning process (Roth, 1990). In addition, constructivism, which emphasizes that knowledge is not independent of the human mind, cannot be transferred among individuals, must be structured by individuals based on their prior knowledge and experience (Hendry, Frommer, & Walker, 1999), is a leading approach in the process of concept formation and conceptual understanding. Constructivism emphasizes that the learning process should take place in meaningful contexts, and what has been learned will be meaningless unless put into practice (Marra, Jonassen, Palmer, & Luft, 2014). Piaget, who has one of the biggest influences on the rise of constructivism (Schunk, 2012), has defined a learning process in which individuals create meaning with the dynamic cognitive schemas they have created as a result of their experiences (Scott, Asoko, & Leach, 2007). These schemas are sets of information that define the concepts that exist in individuals' minds and the relationships among concepts (Roth, 1990). Individuals create various conceptual structures in their mental schemas based on experiences in their own lives. When the new concepts that individuals encounter are compatible with their existing schemas, they include them in their existing schemas; this is assimilation (Scott et al., 2007). However, a cognitive imbalance occurs when the concepts that individuals encounter are incompatible with their existing schemas (Abraham, 2005). In this case, individuals enter into the process of organizing their existing schema or creating a new schema; i.e. accommodation (Zhiqing, 2015). Cognitive development can only occur when there is a cognitive imbalance or cognitive conflict (Schunk, 2012). Learners need to change their current non-scientific concepts with correct concepts by experiencing cognitive conflict in order to form the correct conceptual understanding. In this context, PBL comes across.

PBL is basically based on the constructivist assumption (Loyens, Rikers & Schmidt, 2006; Marra et al., 2014). Promoting experiential active learning, PBL focuses on supporting the formation of knowledge (Torp & Sage, 2002). Conceptual understanding refers to the ability to integrate the theoretical knowledge existing in the mind of the individual into practice in different events and situations (Darmofal, Soderholm, & Brodeur, 2002). PBL uses real world problems to help learners identify concepts and information they want to know and integrate them into practice (Duch, Groh, & Allen, 2001). This shows that PBL can be effective in forming a conceptual understanding. In PBL, while students determine the concepts they need to know in order to solve the problem, they actually enter the conceptual change process required for conceptual understanding. Trying to create meaning between what we know and what we want to know about the problems in the PBL includes incompatibility, and trying to solve this incompatibility is the essence of knowledge construction (Marra et al., 2014). Learners conduct a pre-discussion in small groups about the problem situations in order to activate their own prior knowledge in PBL (Wood, 2003). These pre-discussions support to create new cognitive structures by enabling learners to encounter different views (Dolmans, Wolfhagen, Van Der Vleuten, & Wijnen, 2001). The opportunity for learners to question their own concepts when confronted with different views may cause renewal and change in the cognitive structures of the learners. This situation may foresee that different views may create cognitive conflict.

In this case, PBL aims to provide a cognitive conflict that will initiate the conceptual change process required for a correct and valid conceptual understanding (De Grave, Boshuizen, & Schmidt, 1996). Cognitive conflict is an important factor in the basis of the conceptual change required for correct conceptual understanding (Hadjiachilleos, Valanides, & Angeli, 2013; Lee, Kwon, Park, Kim, Kwon, & Park, 2003).

In addition, small group discussions support the formation of explanatory statements beyond activating learners' prior knowledge and concepts during the problem analysis process (Schmidt et al., 1989). Learners form a hypothesis for the solution of the problem situation based on these explanatory statements. At this stage, learners experience a discussion within the learning groups by giving reasons to validate or reject views to support own conceptual understanding. Throughout this discussion, learners try to convince each other about the validity of their arguments beyond developing arguments made up of claims, evidence, and reason (Aydeniz & Dogan, 2016). Discussion can make connections between isolated facts and concepts (Venville & Dawson, 2010). In this sense, these processes in PBL are an important tool in structuring correct conceptual understanding on the basis of valid scientific realities. Learners who identify learning subjects that include the concepts they do not know and need to learn, evaluate hypotheses in the light of their new knowledge after going through the self-direction learning process (Hmelo-Silver, 2004). These stages offer learners the opportunity to integrate their concepts into a new situation. Since learners discuss the relationships between concepts and principles, transmit their knowledge and concepts into problem situations, integrate different literature sources as a result of their self-direction learnings, it is assumed that the PBL encourages deep and comprehensive learning process (Dolmans, Loyens, Marcq, & Gijbels, 2016). In this learning process, learners have the opportunity to notice their current concepts and change their wrong concepts in order to reach the correct conceptual understanding. This situation reflects the conceptual change process. Problem situations that PBL uses as a focus and the process of finding solutions to them triggers the conceptual change process required to reach conceptual understanding. Within all this capacity, there is a strong structure in which the PBL supports conceptual understanding.

Problem-Based Learning

Constructivism theory, which aims to understand how individuals construct information in their mind, views meaning not as independent from the individual, but structured by the individual (Uden & Beaumont, 2006). In PBL, individuals build new knowledge based on their existing knowledge (Awang & Ramly, 2008). In this sense, it can be said that PBL is related to constructivism. PBL based on the educational principles and practices of the constructivist approach theoretically (Savery & Duffy, 1995), emerged in Case Western Reverse University in the United States in the 1950s and in Medical schools at McMaster University in Canada in the 1960s (Uden & Beaumont, 2006). Since then, PBL approach has been applied in many disciplines (Savery, 2006). There are many definitions in the literature. Savery (2006) defines PBL as a didactic approach that requires research, questioning, putting theoretical knowledge into practice, and using knowledge and skills to find solutions. Barrows and Tamblyn's (1980) PBL definition is learning that occurs through the process of understanding and problem-solving.

PBL is a teaching method that uses problems as a focus provider and encouraging (Boud & Feletti, 1997), and involves cognitive and interrogator processes in which problems are the starting point in learning, and actively facilitates the construction of knowledge (Reynolds & Hancock, 2010). PBL is experiential learning organized around researching and solving real-world problem situations (Torp & Sage, 2002). In traditional learning approaches that present information ready, the problems are given after necessary concepts and information, while in the PBL approach, the problem is the starting point of the learning process (Chin & Chia, 2006). The learning subject in PBL is integrated into real-world problem situations (Hmelo-Silver, 2004), and the presentation of problem situations at the beginning of the learning cycle allows creation of content for the learning process (Prince, 2004). These problem situations, presented by fusing them into learning scenarios in PBL, have been created in a complex structure regarding real life and the concepts and principles in the learning process (Dahlgren &

Öberg, 2001). These problem situations are classified by Jonassen and Kwon (2001) as *well-structured* and *ill-structured*. Well-structured problems are those in which elements related to the problem are presented, and whose real-life transferability is very low, the problems are not too complex, and require a limited number of principles and rules to find the possible solution (Jonassen, 1997). On the other hand, ill-structured problems have many features and multiple solution methods (Chin & Chia, 2006). Ill-structured problems require use of metacognitive skills and knowledge related to various fields, beyond what is known about the subject represented in the problem situation (Chen & Bradshaw, 2007). Ill-structured problems are frequently encountered in daily life, usually require the integration of information about more than one discipline, and include more than one option for the solution (Jonassen, 1997). PBL consists of ill-structured problems that usually deal with real life problems, require connection between concepts and facts, and have multiple and complex solution processes (Lohman & Finkelstein, 2000).

The learning content aimed to be acquired by students in PBL is organized as problem scenarios shaped within the problem framework, and presented as modules consisting of several sessions (Cantürk-Günhan, 2006). In PBL, learners need to determine the background information about the problem and further information needed, working in small collaborative groups on a problem scenario related to the real world (Hmelo-Silver, 2004). In this process, learners set out to define other required information after systematically organizing their own relevant knowledge regarding the solution of the problem situation which acts as a trigger for learning (Hendry et al., 1999). This promotes understanding of how to organize the conceptual framework, and brings insight into the kind of knowledge needed and ways to structure it (Duch et al., 2001). Later, a hypothesis for the solution is created and is evaluated in the light of new knowledge obtained by working on various scenarios (Hmelo-Silver, 2004). Then the hypotheses are tested. In the last stage, the results are made available and the process is evaluated (Wood, 2003).

Misconceptions and Conceptual Change in the Conceptual Understanding Process

Learners have many pre-concepts and knowledge before the teaching (Duit & Treagust, 2003). Although these pre-concepts and knowledge brought to science lessons are well structured in the learners' minds, they may inconsistent with scientific thought (Treagust, 1988). Such unscientific concepts can be variously expressed by terms such as *misconception* (Fisher, 1985; Helm, 1980), *alternative concepts* (Klammer, 1998; Schoon & Boone, 1998), *common sense belief* (Halloun & Hestenes, 1985), *children's science* (Gilbert, Osborne & Fensham, 1982) and *alternative framework* (Driver, 1981). In this research, however, the term *misconception* is used.

All individuals have misconceptions, as a result of misunderstandings personally created to make sense of the world (Gooding & Metz, 2011). Considering that science education is aimed at developing learners' conceptual understanding (Gavalcante, Newton & Newton, 1997; Smith, Blakeslee & Anderson, 1993), it is important to identify their misconceptions and replace these using a conceptual change process. The conceptual change model of Posner, Strike, Hewson and Gertzog (1982) can be considered as a conceptual change framework structure. According to this model, for change to occur, the new concept must meet the conditions of intelligibility, plausibility, and fruitfulness, bringing dissatisfaction with the currently-held concept (Posner et al., 1982). The first condition for conceptual change is intelligibility (Hewson & Thorley, 1989), referring to understanding what the new concept means (Hewson & Hewson, 1983) and how to construct it (Posner et al., 1982). Plausible condition implies the belief that the new concept can be integrated with the learner's existing concepts (Hewson & Hewson, 1983). Dissatisfaction refers to the situation experienced when the currently-held concept is insufficient to solve the problem (Posner et al., 1982), and fruitfulness represents the functionality of the new concept in solving problems (Hewson & Hewson, 1983).

Hewson and Hewson (1984) state that disagreement between the existing and new concepts causes difficulty in the learning process, and in order to prevent this, the existing concept should be reconstructed or replaced. Therefore, conceptual change is necessary and important for the learning

IOJPE

process to reach its goal. Learners who realize the inaccuracy of their own concepts and their inadequacy in problem-solving will be guided to the correct concepts through conceptual change. It can be said that realizing their misconceptions is an important step in this process. Traditional learning processes, involving passive listening does not actively engage the learners' minds or provide much opportunity for them to become aware of their misconceptions (Darmofal et al., 2002). Similarly, Fisher (1985) also states that traditional learning methods are insufficient to eliminate misconceptions. It can thus be understood that the structure of traditional learning does not direct learners to conceptual change. In this sense, it is important to adopt learning approaches that allow learners to realize their own misconceptions, and to see if their concepts are sufficient in understanding the content of learning and solving problem situations, i.e., PBL.

Problem-Based Learning in Providing Conceptual Understanding and Eliminating Misconceptions

PBL, which enables learners to access information content by engaging with real-life problem situations, provide learners to gain experience as active learners with a guide (Hmelo-Silver, 2004). In the PBL process, teachers have a facilitating role as well as a guide (Barrows, 1996). Students are at the center of the learning process. Learners involved with various disciplines have the opportunity for preliminary experience in solving real-life problems by transferring the knowledge acquired via self-directed learning to new problem situations (Stepien & Gallagher, 1993). When learners discover new methods for solving the problem, they are able to integrate their conceptual knowledge into the implementation in the solution phase (Roh, 2003). This allows students to test the accuracy and effectiveness of their current concepts. In PBL, students construct hypotheses based on their solution suggestions by using their preliminary concepts for the problems in the scenario. When testing their hypotheses with the information obtained in the later parts of the scenario, they begin to question existing concepts. They then come to doubt about the reliability of these concepts and gain awareness through experience about these concepts' functionality and validity. In this way, learners area able to assess their existing conceptual structures, and their misconceptions, beyond generalized discourses through personal experience. Such a process is an important step for conceptual change. It is important to identify misconceptions in order to reach the correct conceptual understandings. Posner et al. (1982) state that one of the conditions for the realization of conceptual change is that learners should first experience dissatisfaction, and realize that their current concepts are inadequate. PBL provides such a process, promoting conceptual change.

In terms of PBL structure, it involves learners working in small groups to obtain information, discuss and integrate information regarding problem situations (Goodman, 2010). In PBL, learners reflect on their knowledge, by listening to the ideas of others, while engaged in finding various possible solutions (Erickson, 1999). Therefore, each student involved in the PBL process becomes aware of their own pre-concepts during these discussions. This situation may cause students to encounter with different opinions, question their current concepts and realize their misconceptions, if any. PBL process thus appears as an opportunity to initiate the conceptual change process in order to reach a valid conceptual understanding. In this context, it can be said that PBL is an effective method for replacing incorrect concepts with scientifically correct ones. From this point of view, PBL can help learners in structuring their knowledge, as based on scientific explanations, as basic concepts are perceived in more complex and abstract ways in science.

The concrete foundations of the concept of electricity, one of the most fundamental concepts of science, are generally imparted via simple electric circuits at primary level. Learning the concepts related to simple electric circuit, which is the basis of the study of electricity, helps students to learn related subjects and concepts. Considering that the knowledge structuring starts from the early ages (Wild, Hilson & Hobson, 2013), basic education is a key stage in education. In this context, primary school teachers have great roles and responsibilities. For this reason, it is very important for educators to be able to clearly articulate the concepts in related subject field and to eliminate their misconceptions. Pre-service primary school teachers should therefore be trained in an environment that promotes these qualities. In this research, it is assumed that PBL will overcome pre-service primary school teachers' misconceptions regarding simple electric circuits, and improve their conceptual understanding. There are many studies that investigate conceptual understandings and misconceptions at various levels of education, using different methods and models, regarding simple electric circuits and related concepts (Afra, Osta & Zoubeir, 2009; Aykutlu & Şen, 2012; Bostan Sarıoğlan & Abacı, 2017; Cohen, Eylon, & Ganiel, 1983; Demirezen & Yağbasan, 2013; Dupin & Johsua, 1987; Farrokhnia & Esmailpour, 2010; Fredette & Lochhead, 1980; Jaakkola, Nurmi, & Veermans, 2011; Kalaya, Nopparatjamjomras, Chitaree, & Nopparatjamjomras, 2019; Manunure, Delserieys, & Castéra, 2019; Millar & King, 1993; Picciarelli, Di Gennaro, Stella, & Conte, 1991; Setyani, Suparmi, Sarwanto, & Handhika, 2017; Shepardson & Moje, 1994; Shipstone, 1988; Suciatmoko, Suparmi, & Sukarmin, 2018; Suryadi, Kusairi, & Husna, 2020; Şenyiğit, 2020; Türkoğuz & Cin, 2013; Villarino, 2018; Widodo, Rosdiana, Fauziah, & Suryanti, 2018; Zacharia & de Jong, 2014). However, no study was found that specifically examines the effect of PBL on conceptual understanding and misconceptions of pre-service primary school teachers regarding simple electric circuits. This research aims to fill this gap in the literature by examining the effect of PBL on elimination of misconceptions about simple electric circuits and improving conceptual understanding. The main aim of this research is to investigate PBL's effects on conceptual understanding and misconceptions, with the following research questions:

Research Questions

- ✓ Does PBL improve pre-service primary school teachers' conceptual understanding of simple electric circuits at a significant level?
- ✓ Does PBL decrease pre-service primary school teachers' misconceptions about simple electric circuits at a significant level?

METHOD

Research Model

The pre-test and post-test nonequivalent control group model design was used in the research. This design, one of the most common experimental designs includes an experiment and a control group; the subjects are not randomly assigned, but efforts were made to ensure the similarity of the groups (Campbell & Stanley, 1963). In the nonequivalent control group model, both the experimental and control groups are subjected to a measurement before and after the implementation (West, Biesanz, & Pitts, 2000).

Research Design and Implementation

This research includes an experimental and a control group; PBL was used in the experimental group, and lecture-based learning supported by problem solving, question-answer, discussion activities and demonstration experiments in the control group. A pre-test was applied to both groups to determine their conceptual understanding and misconceptions regarding simple electric circuits, and after the implementation, the same test was applied as a posttest, in order to determine any changes in these.

Materials

Experiment materials required for participants in experimental group to design experimental setups and the activity sheets containing scenarios regarding PBL and are among the main materials used in the research.

Problem-based Scenarios

In the experimental group, in which PBL was applied, the lessons involved activity sheets containing problem-based scenarios prepared by the researcher. While preparing the scenarios, firstly the literature on simple electric circuits was scanned to identify the common misconceptions. The next step was to identify targeted learning outcomes for teaching within the framework of the concepts of closed circuit, open circuit, short circuit, internal resistance, equivalent resistance, ohm law, lamp brightness (electrical power) on subject of simple electric circuits. Then, researcher prepared scenarios for achieving these learning outcomes. The scenarios contain ill-structured problems that involve more than one solution, and reflect real life. Later, two science education experts who worked in the subject of PBL were consulted, and the scenarios were adjusted accordingly. Necessary corrections were made after expert opinions. One correction was the revision and restructuring of scenarios so that they provided more than one solution option. Another important correction was the revision of language and narration, to reflect more realistic daily life situations, with a more detailed narrative. After the corrections made, the final version of the activity sheets was obtained. In the activity sheets containing problem scenarios, empty boxes were provided under each question for participants to write their answers.

Experiment Materials

In the research, the researcher provided the experimental group with materials for the experimental setup, including batteries, lamps, lamp holders, conductive wires, switches, ammeters, voltmeters. Care was taken to ensure that the sufficient materials were available to allow the implementation to be carried out flexibly. These materials were checked before the implementation and those that were not intact were removed.

Experimental Process

The implementations in the experimental and control groups were carried out over 4 weeks by the researcher during the face-to-face training process. Before the experimental procedure, the experimental group participants were divided into groups of 4-5, in a way that ensured heterogeneity within groups and homogeneity between groups. Participants in the experimental group were informed about the PBL process and its principles before the implementation with a sample scenario before they received activity sheets containing scenarios regarding complex problem situations. The concepts regarding target learning outcomes in the experimental process were presented to the participants within a problem scenario. Care was taken to present the relevant concepts in a specific order in problem situations; for example, the concept of closed circuit was presented before the concept of open circuit and short circuit. Scenarios in the research were handled in sessions. The experimental process was carried out over a total of 4 weeks, 3 lesson hours (135 minute) per week. Three course hours were allocated for each scenario in the experimental process. This research was carried out in 12 sessions, in total including 4 scenario consisting of 3 sessions. These were conducted on the basis of the session steps for the scenarios, consisting of 3 sessions each, as explained by Musal, Akalın, Kılıç, Esen, and Alıcı (2002). Accordingly, after reading the scenarios in the first session, the participants examined the problem situation presented, and summarize the information. Then, the participants determined the problem situation based on their prior knowledge. Later, the participants formed a hypothesis by brainstorming the problem situation. Subsequently, the participants determined what they need to know in order to test their hypotheses. Then, the learning goals were determined and the feedback process was carried out. In the second session, the participants summarized and shared the data they obtained as a result of their individual studies in the previous session. At these stages, the participants were able to benefit from various internet databases and printed resources in the learning environment. Later, in the previous session, the questions about what the participants needed to know were answered. Then, after reading the next part of the scenario, they narrowed down the hypotheses using the newly obtained information. Later, new learning topics were determined and the feedback process was carried out. In the third session, after reading the next part of the scenario, the participants summarized and shared the data they obtained as a result of their individual work in the previous session, and then they reviewed hypothesis in the light of all the data. Then, the participants were asked to design an experiment in which they could test their hypotheses. Finally, it was ensured that the result obtained for the solution was determined by associating the hypotheses with the result of the experiment. The next aim was for the group leaders to present the obtained results to the class in a report and to exchange ideas on the results. Then the feedback process was carried out by summarizing the learning topics.

In the control group with the lecture-based learning, problems on subjects in the activity sheets were handled with traditional question-answer, and problem solving activities. During the course of a lesson, the teacher presented the necessary information and concepts at the beginning of the lesson. Then, the teacher solved problems on simple electrical circuits related to the learned subjects and concepts through mathematical operations on the board. These mathematical operations include basic calculation (addition, subtraction, multiplication and division) and equations on the subject used to solve problems on simple electrical circuits. Later, similar problems were solved individually by the participants. Thus, an improvement was made in the control group by trying to limit the participants' being passive in the learning process. At the same time, lesson-based learning in the control group was supported by demonstration experiments. The aim was to limit the possible biased research results in favor of the experimental group in which experimental implementations were made. After each teaching input, a demonstration experiment was carried out. Control group' participants answered questions about the variables manipulated and their possible effects, especially during demonstration experiments, and they discussed their predictions, ensuring the active involvement. This situation is another improvement made in the control group. Attention was paid to the simultaneous processing of related topics and concepts in both groups.

Study Group

Participants of the research consist of 54 pre-service primary school teachers enrolled in the *Basic Science in Elementary School* course in the 2019 spring semester at the state university. The participants were easily accessible, therefore convenience sampling was used; sampling that is continued until the required sampling size is reached (Cohen, Manion, & Morrison, 2018; Gravetter & Forzano, 2018). All participants were pre-service primary school teachers studying in the first grade. Participants were divided into two groups, so as to ensure homogeneity between groups and heterogeneity within groups, according to their grade point averages of the previous term. The two groups were assigned as the experimental and control groups, with 27 in each. 16 of the participants in the experimental group were female and 11 were male, and in the control group, 17 female and 10 male. The average age of the participants was 18.9.

Data Collection Tool

Simple Electric Circuit Diagnostic Test (SECDT) developed by Peşman (2005) was used as a data collection tool in the research.

Simple Electric Circuit Diagnostic Test (SECDT)

The SECDT, developed by Peşman (2005) was used to determine the misconceptions and conceptual understanding of pre-service primary school teachers in this research. This test is a three-tier test consisting of 12 questions. The first stage is in a traditional multiple-choice test structure (Peşman, 2005). The second stage consists of options that indicate the possible rationale for the answer given in the first stage (Caleon & Subramaniam, 2010). In the third stage, the focus is on the respondent's certainty of the answers given in the first two stages (Peşman, 2005). This test represents a sufficient tool to measure the learning outcomes of the participants. The maximum score that can be taken from the test is 12, and the minimum score is 0. Many analyzes were performed in the test development phase by Peşman (2005) regarding the SECDT used for this research. As result of these, relationship between Score-2 and the confidence score was found significantly positive ($r = .51$, $p <.01$), which is evidence for the construct validity; in addition, Cronbach's Alpha reliability coefficient was determine as .69 (Peşman, 2005). Later, point biserial correlation coefficient, false negative, and false positive values were examined, and acceptable values were determined for content validity (Peşman, 2005).

SECDT is a test developed for a high school level target audience. Participants of the current study group of this research last took courses related to the research topic in the high school. In addition, SECDT's validity and reliability analyzes were conducted in order to determine the applicability for pre-service primary school teachers of the test in this research. For this, SECDT was applied to 232 pre-service primary school teachers outside the study group of this research. The answers based on the *score-3,* which are considered as correct information, were taken into consideration in performing item and reliability analyzes. The arithmetic mean value for the SECDT was 5.73, the standard deviation value was 3.32, and the coefficient of skewness was .362, the coefficient of kurtosis -.697. The difficulty indices of the items in the test were between .35 and .47; the discrimination indices varied between .52 and .78, and the point biserial correlation coefficient values were determined to be .20 and above for each item. In this case, point biserial correlation coefficient values (Crocker & Algina, 1986), item difficulty (Crocker & Algina, 1986), and item discrimination (Ebel & Frisbie, 1986) index values are acceptable. As a result of the reliability analysis of the SECDT performed on 232 participants, the Cronbach's Alpha reliability coefficient was calculated as .81. Hestenes and Halloun (1995) state that the false positive and false negative rates should be below 10% in order to ensure the structure and content validity of the test. In this research, SECDT's *second type misconception score (false positive)* and *third type misconception score (false negative)* were used to determine the false positive and false negative rates, respectively. For this research, the false positive rate was 7.65% and the false negative rate was 3.27%. In this case, the false negative and false positive rates were below 10%, evidence that the SECDT provided content and structure validity for this research. Cataloglu (2002) states that the positive correlation between score-2 type and confidence score is evidence of the test's construct validity. The relationship between score-2 and confidence score type for this research was positive and significant ($r = .45$, $p < .00$). This result is another indicator of the SECDT's construct validity. These results reveal that the SECDT is a valid and reliable test for pre-service primary school teachers. In addition, there are different studies in which SECDT is used on pre-service teachers as a data collection tool (Altun, 2009; Arı, Peşman, & Baykara, 2017).

Data Scoring

The data related to the research were obtained from the SECDT applied to both groups before and after the experimental process. Şen and Yılmaz's (2017) scoring system is thought to be the most up-to-date and comprehensive scoring system for the three-tier tests in the literature, and was used in scoring of the data obtained. According to this scoring system, nine different types of scores can be obtained. This wide-ranging scoring system prevents from evaluating every wrong answer as a misconception, and highlights that that they may also be caused by the lack of information (Şen & Yılmaz, 2017). Using such a detailed scoring system in the research is important factor in the accurate identification of misconceptions.

Şen and Yılmaz (2017) propose three types of scores representing misconceptions: *misconception*, *false positive* and *false negative*. These score types were evaluated under the name of *first*, *second* and *third type misconception score* for this research. Dealing with misconceptions under three sub-headings leads to more detailed results regarding misconceptions. In this research, the score type coded to determine conceptual understanding was evaluated under the name of *conceptual understanding score*. In this case, the results obtained were the conceptual understanding score for conceptual understanding, and three different types misconception scores. Although nine different types of scores can be obtained from Şen and Yılmaz's (2017) system, the focus was on the conceptual understanding scores, and the misconception scores, since the conceptual understanding and misconceptions of the participants were examined in this research. Score-4 and Score-5 are used to determine lack of information and lack of confidence/lucky guess, respectively (Şen & Yılmaz, 2017). Since the aim of the research is to determine conceptual understanding and misconceptions, these score types (Score-4 and Score-5) were not used. Detailed information about score types, and how to code them for the data analysis process is provided below.

Score-1: This type of score calculated by examining the answers given only in the first stage is obtained by scoring of the condition that the participants gave correct answer in the first stage, as 1, and the incorrect answer as 0 (Şen & Yılmaz, 2017).

Score-2: This type of score calculated by examining the answers given in both the first and the second stages is obtained by scoring of the condition that the participants gave correct answers in the first and second stages, as 1, and all other situations as 0 (Şen & Yılmaz, 2017).

IOJPE

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International Online Journal of Primary Education 2021, volume 10, issue 1

Score-3 (Conceptual understanding score): This scoring type represents the scientifically correct answers given by the participants. This type of score is obtained by scoring of the condition that the participants gave correct answers in the first and second stages and were sure of their answers, as 1, and all other situations as 0 (Şen & Yılmaz, 2017). This type of score, coded as Score-3 by Şen and Yılmaz (2017) was explained as the *conceptual understanding score* in this research.

Score-6 (First type misconception score (misconception)): This type of score is obtained by scoring of the condition that the participants gave incorrect answers in the first and second stages, and were sure of their answers, as 1, and all other situations as 0 (Şen & Yılmaz, 2017). This type of score, coded as Score-6 by Şen and Yılmaz (2017) was explained as the *first type misconception score* in this research.

Score-7 (Second type misconception score (misconception, false positive)): This type of score is obtained by scoring of the condition that the participants gave correct answers in the first stage, incorrect answers in the second stage, and were sure of their answers, as 1, and all other situations are scored as 0 (Şen & Yılmaz, 2017). This scoring is a misconception type, it indicates that the respondents give the correct answer with a wrong justification, and are sure of their answers (Şen & Yılmaz, 2017). This type of score, coded as Score-7 by Şen and Yılmaz (2017) was explained as the *second type misconception score* in this research.

Score-8 (Third type misconception score (misconception, false negative)): This type of score is obtained by scoring of the condition that the participants gave incorrect answers in the first stage, correct answers in the second stage, and were sure of their answers, as 1, and all other situations are scored as 0 (Şen & Yılmaz, 2017). This scoring is a misconception type, it indicates that the respondents give the wrong answer with a correct justification and are sure of their answers (Şen & Yılmaz, 2017). This type of score, coded as Score-8 by Şen and Yılmaz (2017) was explained as the *third type misconception score* in this research.

Score-9 (Confidence score): In this score type, only the answers to the third stage are taken into account (Şen & Yılmaz, 2017). The answers given are coded as 1 if "I am sure" and 0 if "I am not sure". This type of score, coded as Score-9 by Şen and Yılmaz (2017) was explained as the *confidence score* in this research.

Data Analysis

SPSS Statistics 23 program was used for data analysis. In data analysis, the level of significance was evaluated as .05. Analysis was conducted using arithmetic mean, standard deviation, percentage value, independent samples t-test, paired samples t-test, One-way MANOVA, and One-way repeated measures MANOVA. The purpose of using the independent samples t-test is to determine the significance of the difference between the arithmetic means of data values obtained from two independent or unrelated groups (Morgan, Leech, Gloeckner & Barrett, 2011). Independent samples t-test was used to compare the mean score of the groups regarding conceptual understanding before and after the implementation. Before the test, the assumptions were checked. The independent samples t-test assumption is that the data are suitable for normal distribution and the variances are equal (Cronk, 2020). Tabachnick and Fidell (2019), and Ntoumanis (2001) state that the normality assumption can be evaluated with the coefficients of skewness and kurtosis. George and Mallery (2020) state that the coefficients of skewness and kurtosis between ± 2.0 are acceptable. The results of the analysis showed that the experimental group pretest (Skewness= .374; Kurtosis= .769), the control group pretest (Skewness= -.400; Kurtosis= -.20), the experimental group posttest (Skewness= .100; Kurtosis= -1.226), and the control group posttest (Skewness= -.805; Kurtosis= .417) data for the conceptual understanding were suitable for normal distribution. Levene’s test results for equality of variances regarding the pretest mean scores ($p= .585$, $p>.05$) and the posttest mean scores ($p= .70$, $p>.05$) of the experimental and control groups revealed no significant difference between the variances of the groups. The paired samples t-test is performed to determine the significance of the difference between the arithmetic mean values of the data obtained as a result of successive measurements over the same data source (George & Mallery, 2020). Paired samples t-test was conducted to determine whether the conceptual understanding of the groups improved significantly compared to the pre-implementation. The paired samples-t test assumes that the data shows a normal distribution and are measured with the same scale (Cronk, 2020). Before the test, the normality condition was checked by calculating the values of skewness and kurtosis coefficient. Accordingly, the skewness and kurtosis coefficient values were obtained from the averages of the experimental group's the posttest pretest difference score and the control group's posttest pretest difference score. The results of the analysis showed that the experimental group's posttest pretest difference score (Skewness= .389; Kurtosis= -1.089), control group's posttest pretest difference score (Skewness= .012; Kurtosis= .059) data were suitable for normal distribution. These results revealed that the necessary conditions for independent samples t-test and paired samples t-test were met.

One-way MANOVA was used to determine the significance of the difference between misconceptions pretest and posttest mean scores of the two groups. Before the test, normality condition was checked by the coefficients of skewness and kurtosis and multivariate normality condition was checked by calculating Mahalanobis distance values. The analysis results showed that the pre-test and post-test mean scores of the experimental group were suitable for normal distribution regarding the first (Skewness $_{(pretest;\ posttest)}$ = .504; 1.007, Kurtosis $_{(pretest;\ posttest)}$ = .230; .670), second (Skewness $_{(pretest;\ posttest)}$ = 1.634; .237, Kurtosis $_{(pretest;\ posttest)}$ =1.396; -1.106), and third (Skewness $_{(pretest;\ posttest)}$ = 1.691; 1.099, Kurtosis $_{(pretest;\ posttest)}$ = 1.683; 1.594) type misconception. In addition, the analysis revealed that the pre-test and post-test mean scores of the control group were suitable for normal distribution regarding the first (Skewness $_{(pretest;\ posttest)}$ = .671; .262, Kurtosis $_{(pretest;\ posttest)}$ = .075; -.668), second (Skewness $_{(pretest;\ posttest)}$ = 1.567; .422, Kurtosis $_{(pretest;\ posttest)}$ =1.651; -.650), and third (Skewness $_{(pretest;\ posttest)}$ = 1.452; 1.416, Kurtosis $_{(pretest;\ posttest)}$ = 1.379; .649) type misconception. Mahalanobis distance values revealed that there is no multivariate outlier that breaks multivariate normality. Analysis results showed that the data were distributed normally in both cases. Box's M test showed that there is no significant difference between the covariance matrices (Box's M= 6.092, F= .952, p= .457, p>.05). Levene's test showed that error variances for scores of the first type misconception (p= .277, p>.05), the second type misconception (p= .216, p>.05), and the third type misconception (p= .168, p>.05) can be considered equal. One-way repeated measures MANOVA was conducted to determine the significance of the difference between experimental group' the posttest pretest mean scores and control group' the posttest pretest mean scores for each type of misconception. The assumptions required for the validity of the results obtained from the One-way repeated measures MANOVA analysis were examined. Before the test, normality condition was checked by the coefficients of skewness and kurtosis. The analysis results showed that the post-test pre-test difference scores of the experimental and control groups were suitable for normal distribution regarding the first (Skewness $_{(experimental;\ control)}$ = .662; -.236, Kurtosis $_{(experimental;\ control)}$ = .355; .248), second (Skewness $_{(experimental;\ control)}$ = -1.264; -.664, Kurtosis $_{(experimental;\ control)}$ = 1.661; .510), and third (Skewness $_{(experimental;\ control)}$ = -.997; -1.108, Kurtosis $_{(experimental;\ control)}$ = .852; 1.298) type misconception. Mauchly's test of Sphericity results showed that there was no significant difference between the variances of the difference scores (p=.065, p> .05). These results revealed that the necessary conditions for One-way MANOVA and One-way repeated measures MANOVA were met.

RESULTS

Conceptual understanding score was used to determine the effect of the method applied on the participants' conceptual understanding of basic electric circuits. *First type misconception score (misconception)*, *second type misconception score (false positive)* and *third type misconception score (false negative)* were used to determine the applied method's effect on the change of misconceptions. High conceptual understanding mean scores as a result of the scores obtained from the data collection tool are considered as a benefit for participant groups, and the high mean score for misconception types, a drawback.

This section includes, in parallel with the research questions, the results of the analysis of the effect of the method applied on misconceptions and conceptual understanding.

Results Regarding the Change in the Conceptual Understanding

The aim of the first research question is to determine whether there was significant improvement in the conceptual understanding in the experimental and control groups after the implementation. As a result of the analysis of SECDT's conceptual understanding scores, the pretest mean scores of the experimental and control groups were determined as 2.30 and 2.74 respectively. To determine whether this difference was significant, the groups' the pretest mean scores were compared with independent samples t-test (Table 1).

Table 1. Independent samples t-test results regarding conceptual understanding

Group	Pretest						Posttest					
	n	M	SD	df	t	p	n	M	SD	df	t	p
Experimental	27	2.30	1.07	52	1.463	.150	27	7.26	2.18	52	7.814	.000*
Control	27	2.74	1.16				27	3.33	1.44			

*p<.05, M: Mean, SD: Standard Deviation

In the Table 1, the research showed no significant difference between the SECDT's pretest mean scores of the experimental and control groups ($t_{(52)}$=1.463, p>.05). In order to determine the significance of the difference between the SECDT's posttest mean scores of the experimental and control groups in Table 1, independent samples t-test was conducted. Table 1 shows a significant difference between the SECDT's posttest mean scores of the experimental and control groups ($t_{(52)}$=7.814, p<.05).

Then, in order to determine whether there was significant improvement in participants' conceptual understanding in the experimental and control groups after the implementation compared to before the implementation, paired samples t-test was conducted related to conceptual understanding mean scores (Table 2).

Table 2. Paired samples t-test results regarding conceptual understanding

Group	Experimental						Control					
	n	M	SD	df	t	p	n	M	SD	df	t	p
Pretest	27	2.30	1.07	26	11.579	.000*	27	2.74	1.16	26	1.728	.096
Posttest	27	7.26	2.18				27	3.33	1.44			

*p< .05, M: Mean, SD: Standard Deviation

In the Table 2, the research showed a significant difference between SECDT's pretest and posttest mean scores of the experimental group ($t_{(26)}$=11.579, p<.05). In addition, Table 2 indicates no significant difference between SECDT's pretest and posttest mean scores of the control group ($t_{(26)}$=1.728; p>.05). Table 3 shows the conceptual understanding percentages in the experimental and control groups.

Table 3. Percentages of conceptual understanding regarding experimental and control groups

Group	Conceptual understanding (%)
Experimental pretest	19.12
Experimental posttest	60.49
Control pretest	22.82
Control posttest	27.76

Table 3 reveals that the experimental group's conceptual understanding was 32.73% higher than the control group's after the implementation compared to before the implementation.

Results Regarding the Change in the Misconceptions

The aim of the second research question was to determine whether there was a significant decrease in misconceptions in the experimental and control groups after the implementation. In order to determine

IOJPE
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International Online Journal of Primary Education
2021, volume 10, issue 1

the significance of the difference between the pretest and posttest mean scores of the two groups regarding SECDT's misconception score types in Table 4, One-way MANOVA analysis was conducted (Table 4).

Table 4. One-way MANOVA test results regarding misconception score types

Misconception score types	Group	Pretest n	M	SD	F	p	Posttest n	M	SD	F	p
First type misconception	Experimental group	27	3.30	1.49	1.076	.304	27	1.63	1.39	7.929	.007*
	Control group	27	2.89	1.40			27	2.82	1.69		
Second type misconception	Experimental group	27	.48	.89	.024	.877	27	.44	.51	2.579	.114
	Control group	27	.52	.85			27	.70	.67		
Third type misconception	Experimental group	27	.48	.85	.103	.750	27	.15	.36	.477	.493
	Control group	27	.56	.85			27	.22	.42		

*p< .05, M: Mean, SD: Standard Deviation

Table 4 reveals no significant difference between groups' pretest mean scores regarding the first type misconception (F=1.076, p>.05), the second type misconception (F=.024, p>.05), and the third type misconception (F=.103, p>.05). Wilks' Lambda analysis results showed a significant difference between the experimental and control group regarding SECDT's posttest misconception mean scores ($F_{(3\text{-}50)}$=3.624, p=.019, p<.05, Wilks' Λ=.821, partial η^2=.179). Table 4 indicates significant difference between groups' posttest mean scores regarding the first type misconception (F=7.929, p<.05), but no significant difference between the posttest mean scores regarding the second (F=2.579, p>.05) and the third type misconception (F =.477, p>.05).

One-way repeated measures MANOVA analysis was conducted to determine whether there was significant decrease in misconceptions in the experimental and control group after the implementation compared to before the implementation (Table 5).

Table 5. One-way repeated measures MANOVA results regarding misconception score types

Misconception score types	Test	Experimental group n	M	SD	F	p	η^2	Control group n	M	SD	F	p	η^2
First type misconception	Pretest	27	3.30	1.49	15.476	.001*	.373	27	2.89	1.40	.047	.830	.002
	Posttest	27	1.63	1.39				27	2.82	1.69			
Second type misconception	Pretest	27	.48	.89	.031	.861	.001	27	.52	.85	.632	.434	.024
	Posttest	27	.44	.51				27	.70	.67			
Third type misconception	Pretest	27	.48	.85	3.000	.095	.103	27	.56	.85	3.900	.059	.130
	Posttest	27	.15	.36				27	.22	.42			

*p< .05, M: Mean, SD: Standard Deviation

Table 5 shows significant difference between experimental group' posttest and pretest mean scores regarding the first type misconception (F=15.476, p<.05), but no significant difference between the posttest and pretest mean scores for the second type misconception (F=.031, p>.05) and the third type misconception (F=3.000, p>.05). Table 5 indicates no significant difference between control group' posttest and pretest mean scores regarding the first type misconception (F=.047, p>.05), the second type misconception (F=.632, p>.05), and the third type misconception (F=3.900, p>.05). Table 6 shows the misconception percentages of the participants in the experimental and control groups.

Table 6. Percentages of misconception regarding experimental and control groups

Group	First type misconception (%)	Second type misconception (%)	Third type misconception (%)
Experimental pretest	27.45	4.32	4.01
Experimental posttest	13.57	3.7	1.23
Control pretest	24.05	4.32	4.63
Control posttest	21.89	5.86	1.85

Table 6 reveals that the first type (8.32%), the second type (2.16%), and the third type (.62%) misconception percentage was lower in the experimental group compared to the control group after the implementation.

DISCUSSION and CONCLUSION

This research focused on comparing the effect of PBL and lecture-based learning in improving conceptual understanding of simple electric circuits, and eliminating misconceptions. The results support the assumption that PBL stated at the beginning of the research will be more effective in improving conceptual understanding and in decreasing misconceptions when compared to the lecture-based learning. diSessa (2014) states that for some difficult subjects, conventional teaching methods are often unsuccessful. The teaching of concepts, such as closed circuit, open circuit, short circuit, internal resistance, equivalent resistance, ohm law, electrical power in the subject field of simple electrical circuits is generally limited to the mathematical operations for problem solving in lecture-based learning. Explanations for these concepts in lecture-based learning, however, are likely to remain abstract in the minds of learners. The abstract structure of the subjects and concepts, in particular, may make it difficult for learners to structure these concepts correctly, and gain conceptual understanding. Gavalcante et al. (1997) states that the conceptual understanding cannot simply be transferred to the learners; they should construct it themselves. For this reason, learners should be given the opportunity to construct these concepts in real-life learning situations, rather than listening to verbal explanations, for correct interpretation. Thus, learners may be more likely to realize the inaccuracy of their own abstract explanations, and embrace scientific explanations that will provide correct conceptual understanding. Bilgin, Şenocak, and Sözbilir (2009) state that PBL is among the various learning approaches developed by researchers to improve conceptual learning skills, as an alternative to moving away from memorization. PBL includes problem situations that are used to increase knowledge and understanding (Awang & Ramly, 2008). Iglesias (2002) states that PBL, which is characterized by posing real-life problems, enables learners to acquire basic concepts for certain content fields. In this research, in the experimental group, concepts in the subject field of simple electric circuits were studied through scenarios involving real-life problem situations. In this way, learners have the opportunity to transform their abstract explanations and misconceptions into correct scientific explanations through concrete implementation. Research results support these explanations. The maximum score that can be obtained from the SECDT for conceptual understanding is 12. However, before the implementation, this score was found to be 2.30 in the experimental group and 2.74 in the control group. This highlights the low conceptual understanding, of the pre-service primary school teachers in the participant group before the implementation. These scores for conceptual understanding were found to be 7.26 in the experimental group and 3.33 in the control group at the end of the implementation. In the light of the findings obtained, the research showed that PBL is significantly more effective in improving conceptual understanding regarding simple electric circuit compared to lecture-based learning. PBL made a 32.73% greater contribution in improving conceptual understanding compared to lecture-based learning. In the literature, existing studies support this result, and show that PBL has positive effects on conceptual understanding and concept learning. Sahin (2010) concluded that PBL has a more positive effect on university students' conceptual understanding of Newtonian Mechanics compared to traditional instruction. Günter, Akkuzu, and Alpat (2017) determined that PBL has more positive effects on the understanding of *green chemistry* and *sustainability* compared to traditional expository learning. Wardani, Nurhayati, and Hardiyanti (2017) found that PBL model more positive effect the conceptual understanding of students compared to the lecture-based learning. Eren and Akınoğlu (2012) determined that PBL has a significantly greater positive effect on concept teaching compared to the lecture-based learning. Nangku and Rohaeti (2019) found that PBL model positively affected students' conceptual understanding. Ahied and Ekapti (2020) concluded that learning using PBL can improve students' conceptual understanding of pressure concept. In addition, there are studies regarding the positive effects of PBL supported by various methods and techniques on conceptual understanding. Pratiwi, Cari, Aminah, and Affandy

(2019) determined that PBL applying argumentation skills improves learners' conceptual understanding regarding relationship between buoyant and sinking volume. Zahro, Jumadi, Wilujeng, and Kuswanto (2019) determined that web-assisted PBL model resulted in a higher conceptual understanding compared to the traditional learning model. Rohmah, Pramono, and Yusuf (2020) stated that PBL supported by mobile learning media can improve primary students' conceptual understanding, and Ula, Supardi, and Sulhadi (2018) concluded that the implementation of PBL with mind mapping improves understanding of concepts.

In this research, the participants with misconceptions in general were more likely to give wrong answer with the wrong reason, rather than reaching the wrong answer with the correct reason, or the correct answer with the wrong reason. Thus, of the three sub-score of misconception examined, the mean scores for the first type misconception are higher than for the others. The research showed that PBL provided a decrease in all misconception types at the end of the implementation, but this decrease was significant only for the first type. Consistent with this result, the research revealed that PBL provided a 13.88% decrease for the first type misconception at the end of the implementation compared to before the implementation. The fact that the research was limited to 4 weeks can be shown as the reason why the decrease in other misconception types was not significant. The results revealed that the lecture-based learning after the implementation provided a non-significant decrease in the first and third types of misconception, and a non-significant increase in the second type. Based on this result, in the control group, after the implementation, there was an increase in the numbers giving the correct answer based on the wrong reason, and being sure of the answers. Percentage changes in misconception score types are consistent with this result. The research showed that lecture-based learning increased the second type misconception (false positive) by 1.54% at the end of the implementation. This increase in the second type misconception, as opposed to a decrease or no change, was an unexpected result. However, this increase was not significant. The lack of a significant increase may be a reason for optimism about the effect of this result. The cause may be that participants are likely to reach correct answers in their predictions results, even without the correct justification. Hestenes and Halloun (1995) states that it is difficult to reduce the rate of false positives, and that even random choices are effective in increasing the rate of false positives. This explanation supports the result obtained.

The research revealed that PBL was effective 13.88% and lecture-based learning was 2.16% effective in decreasing the first type misconception after the implementation. It was previously stated that some improvements were made in the control group in order to limit the results of the biased research in favor of the experimental group in which the experimental implementations were made. Accordingly, in order to ensure the activeness of the participants in the control group, question-answer and problem solving activities were carried out. In addition, during the demonstration experiments used in the control group, a discussion environment was provided on the predictions of the control group participants. However, unlike lecture-based learning, PBL provides an opportunity for learners to think about the solution of a problem situation, to form a hypothesis and test it. In PBL, learners make pre-discussions based on their pre-knowledge to determine the problem and its solution. These discussions cause learners to encounter different ideas and question their own concepts. In addition, the process of creating and testing hypotheses provides an opportunity for learners involved in the learning process with their pre-concepts to question their existing concepts and realize that they are wrong. Thus, learners enter a process that will replace their misconceptions with scientific explanations. The inability of lecture-based learning to have a significant effect on overcoming misconceptions in this research can be attributed to these reasons. Widarti et al. (2017) states that lecture-based learning will be insufficient in overcoming misconceptions related to conceptual change. PBL was significantly effective in overcoming misconceptions, but did not completely eliminate misconceptions. This is probably because the participants had a lot of misconceptions before the implementation. Perhaps the success of PBL could be seen more clearly if it had been studied with a group of participants who had less misconceptions before the implementation. But still the research revealed that PBL is more effective at overcoming misconceptions of all types than lecture-based learning. The research showed that PBL is more effective by 8.32% at decreasing misconception compared to lecture-based learning. This shows the success of PBL in overcoming misconceptions. These results confirmed the assumption that PBL presented in the research is effective in decreasing misconceptions. In the literature, there are studies that support the effectiveness of PBL in decreasing misconceptions. Akınoğlu and Tandoğan (2007) determined that the PBL model not only positively affected the conceptual development, but also kept misconceptions at a low level. Tarhan and Acar (2007) found that PBL compensates for misconception in students, and Bayram (2010) found that PBL is more successful in eliminating misconceptions compared to traditional learning methods. The PBL method applied in this research was more effective in decreasing the participants' misconceptions about simple electric circuits compared to the lecture-based learning and had a more positive effect on enabling participants to make scientific explanations about simple electric circuits, and improve their conceptual understanding.

Suggestions

The research results reveal the positive effects of PBL in eliminating pre-service primary school teachers' misconceptions and supporting conceptual understanding, compared to lecture-based learning. This suggests that PBL should be employed more frequently in the education system. This research was carried out on simple electrical circuit issues and concepts, but future studies can be expanded to include other science subjects and concepts. Longer-term research will enable the effect of PBL on variables to be determined more clearly. The current research focused on the elimination of misconceptions within the scope of the general results obtained from the test, but the misconceptions surrounding each concept were not examined individually before and after the implementation. For this reason, it is not known which misconceptions were more resistant to elimination at the end of the implementation. Therefore, in subsequent studies, the results obtained may be supported with qualitative data in order to determine the change of pre-and post-implementation misconceptions for each concept.

Limitations

There are some limitations of the present research. The first limitation of this research was that the research period was limited to four weeks in order to minimize disrupt the education program. This limitation can be overcome by carrying out the research with a longer implementation period to reveal the change in conceptual understanding and misconceptions more clearly. In this research, concepts regarding basic electric circuits were limited to closed circuit, open circuit, short circuit, internal resistance, equivalent resistance, ohm law, lamp brightness (electrical power). In future studies, these concepts can be further expanded taking a holistic approach. The last limitation is that the research data was obtained using three-tier SECDT. In the third stage of the three-tier tests, the participants were asked to confirm whether they were sure of their answers in both stages (Şen & Yılmaz, 2017). Similar research can use a four-tier test to be developed on simple electrical circuits in the literature. Thus, this limitation of the three-tier tests can be eliminated by asking the participants about the certainty of their responses separately for both stages.

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