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The Effect of Peer Instruction (PI) on the Pre-Service Teachers' Learning of Current Electricity

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Abstract

This study was carried out to find out the effects of PI on the pre-service teachers' learning of current electricity. The choice of pre-service teachers is hinged on the importance role teachers play in the student's learning of sciences in schools. The study adopted pretest-posttest quasi-experimental design. 42 students of a College of Education in Nigeria were purposively sampled for the study. Two research questions were answered. Data were collected through Current Electricity Physics Assessment (CEPA) and the Peer Instruction Dialogical Argumentation Questionnaire (PIDAQ). The collected data were analyzed using the descriptive statistics and Analysis of Covariance (ANCOVA). Findings revealed that there is no significant difference in academic performance of students taught with the PI and those with the lecture method. Besides, PI improve students understanding in current electricity and students have many misconceptions in current electricity. The study made some recommendations.

1. Introduction

The choice of this study is hinged on the strategic position of qualified physics teachers in the teaching and learning of physics in Nigerian schools. Besides, the method teachers employ in physics classroom goes a long way to determining how well the students will learn.

Studies show that teachers' strategy or method of teaching is one of the causes of poor students' academic performance in physics courses (Wanbugu, Changeiywo, & Ndiritu, 2013).

The teacher is expected to make students actively involved in the classroom because observation made by McCarthy and Anderson (2000) was that active learning stimulates inquiry.

However, research studies show that the traditional lecture approach still dominates teaching in most post-secondary schools (Deslauriers, Schelew, & Wieman, 2011). Scholars argued that the present way of teaching physics must be changed because it is boring and uninteresting to young students. According to Rodrigues and Oliveira (2008) this method does not meet the actual requirements of society and the new trends of physics curricula.

The most valuable educational resource is the teacher (Boyd, Landford, Loeb, Rockoff, & Wyckoff, 2008). Aaronson, Barrow, and Sander (2007); Rockoff (2004) were of the firm opinion that a teacher could significantly influence students achievement. The quality of any educational system is largely based on the quality of teachers regarding academic and professional qualifications, experience, competency and the level of dedication to their primary functions (Oluremi, 2013).

Teachers are the facilitators who are to impact on students the concepts expected to be learned (Owolabi, 2012). Teachers are the most important factor in the effectiveness of schools and the quality of a child's education (Akinsolu, 2010).

The study of physics depends on the teachers' quality because no education can rise above teachers'quality (Apata, 2013). Without a well-educated, strongly motivated, skilled, well-supported teacher, the arch of excellence in high school physics will collapse (The American Association of Physics Teachers, 2009).

Given the forgone background there is the need to adopt a research-based pedagogy for the pre-service physics teachers. Therefore, the need to investigate the effectiveness of the peer instruction among the pre-service physics teachers becomes imperative.

Peer Instruction is an instructional strategy for engaging students during class through a structured questioning process that involves every student (Crouch, Watkins, Fagen, & Mazur, 2007).

PI provides a structured environment for students to voice their ideas and resolve misunderstandings by talking with their peers (Gok, 2012).Peer instruction is a cooperative learning technique that promotes critical thinking, problem-solving, and decision-making skills (Rao & DiCarlo, 2000) and it was designed to improve the learning process (Rosenberg, Lorenzo, & Mazur, 2006).

PI is more effective at developing students' conceptual understanding than traditional lecture-based instruction (Lasry, Mazur, & Watkins, 2008). According to Crouch et al. (2007), PI increases student mastery of both conceptual reasoning and quantitative problem solving. PI encourages students to take responsibility for their learning and emphasizes understanding (Gok, 2012).

It is not a rejection of the lecture format, but a supplement that can help engage students who have a range of learning styles (Rosenberg et al., 2006).

Peer Instruction engages students during class through activities that require each student to apply the core concepts being presented, and then to explain those concepts to their fellow students. Lectures in PI consist of the short presentations on the main points, each followed by a Conceptest**.** Conceptestis is a short conceptual question, typically posed in a multiple-choice format, on the subject being discussed.

Electricity is an aspect of electromagnetism that physics students offer at all level of education in Nigerian schools. Students start to learn electricity from the Senior Secondary School (SSS) through to the university. However, the literature indicates that students' academic performance in this branch of physics is poor because of many reasons. One of these grounds is attributed to the misconceptions by both the teachers and the students. Classroom experience in the current electricity revealed that it is a topic that has many misconceptions (Engelhardt & Beichner, 2004).

The research conducted and published in 1992 by McDermott, Shaffer and the Physics Education Group at the University of Washington identified specific student difficulties with learning about electric circuits. The research work gave details analysis of the problems arising during the instruction of electricity. The result of McDermott, Shaffer, and the Physics Education Group is germane to the present study.

Electricity is an important and challenging physics topic at all school levels where students often have many difficulties in learning (Jaakkola & Nurmi, 2004). McDermott and Shaffer (1993) research studies conducted on the understanding of electricity revealed that students had difficulties in conceptual understanding.

Concepts of voltage and current in electricity have often appeared foreign to students since they are measurable but not directly visible (Graff, Niemi, Leiffer, & Vaughan, 2007). This is the reason some attributed poor knowledge in electricity to its abstract nature. Mulhall, McKittrick, and Gunstone (2001) in their perspective believe electricity concepts are abstract and difficult to teach.

2. Research Questions

1. Is there any difference between the academic performances of the students taught with the PI and the traditional lecture method in electricity?
2. What impact does the Peer Instruction have on the students understanding of the current electricity?

3. The Purpose of the Study

The purpose of this study is to find out if PI has any effect on students' learning of electricity. Specifically, the effort was made to find out:

If there is any difference between the students taught with the PI and the traditional lecture method; if the PI have any impact on the students' understanding of the current electricity.

4. Research Design

The study is a quasi-experimental of pretest-posttest control group design. The design is an equivalent pretest-posttest because the researcher randomly assigns the participants to groups. The participants are the 2014/2015 academic session students who are randomly divided into the control and the experimental groups.

Pretest-posttest designs are widely used primarily to compare groups and measuring change resulting from experimental treatments (Dimitrov & Rumrill, 2003). The instruments for the study are Current Electricity Physics Test (CEPA) and the Peer Instruction Dialogical Argumentation Questionnaire (PIDAQ)

The instruments were submitted to science education experts and a physics lecturer both at a university in South Africa and a university in Nigeria for validation. This study used inter-scorers reliability which measured the degree of agreement between two or more scorers, judges or raters. Any item scoring an average of 3 or less was discarded. The instrument was administered to the students of a college of education which were non-participants of this study. It was done as a pilot study before the start of the research. The data got were analyzed to determine the reliability of the instrument. The reliability statistics of the instrument was calculated using SPSS software to get the Cronbach's alpha to be 0.876, according to Pallant (2005) Cronbach's alpha above 0.7 is reliable.

5. Procedure

The participants were divided into control and experimental groups. Both groups had eight weeks of lecturing, but the experimental group had PI interspersing with lecture method. Twenty developed conceptests on electricity were used for the lectures. ConcepTests are short conceptual questions, typically posed in a multiple-choice format, on the subject being discussed. The students in this group attended two hours lecture every week. The teacher introduces a conceptest using a projector and gives students two minutes to think about the concepts. After two minutes, students responded to the conceptest by flashcards. When the percentage of the correct answer is more than 70%, the teacher gives a brief summary of the conceptest and move to another conceptest.

When the percentage of the correct answer is less than 70%, the students go into different groups to discuss the answer with their peers. The students were given time to argue out the correct answer in each group. The teacher move around the class to observe and listen to the students as they argued among themselves. The groups selected a leader among themselves to discuss their answer with the whole class while any member of the class may object the answer with reason(s). The teacher concludes the argument session with an explanation on the conceptest as the case demand. The time for this session is 30 minutes.

6. Participants

42 physics students of Aseyori College of Education, participated in this study. The students were purposively sampled because they were in their introductory class. The participants took part in the research voluntarily. When the research started, the participants were made aware as to when, where and how the research will be conducted. The researcher ensured no harm or injury of any form comes to any of the participants as a result of the study. The dignity and integrity of the participant are necessary and was not violated. Anonymity and confidentiality were respected. For anonymity purpose, the real name of the sampled college was replaced by Aseyori College of Education throughout the study.

Electricity as a topic in physics was used for the study because of the research findings that student performs poorly in electricity (Engelhardt & Beichner, 2004; Mulhall et al., 2001).

7. Findings and Discussion

The research question 1 deals with both the control and the experimental group while the research question 2 only deals with the students in the experimental group (EG).

Research question 1: Is there any difference between the academic performances of the students taught with the PI and the traditional lecture method in electricity?

Table-1. ANCOVA.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	68.314[a]	2	34.157	.245	.784	.012
Intercept	6827.468	1	6827.468	49.043	.000	.557
pr	11.080	1	11.080	.080	.779	.002
grp	65.330	1	65.330	.469	.497	.012
Error	5429.305	39	139.213			
Total	42700.000	42				
Corrected Total	5497.619	41				

a. R Squared = .012 (Adjusted R Squared = -.038)

From Table 1, the independent variable (group) has a significant value of 0.497 which is higher than the probability value of 0.05; this implies that there is no significant difference between the groups. There is no significant difference between the independent and dependent variable. Therefore, this indicates that there is no difference in the academic performance of the students who are taught using peer instruction and those taught with traditional lecture method.

The outcome of this study is contrary to many kinds of the literature on the effectiveness of PI. Many believed that PI is more efficient at developing students' conceptual understanding than traditional lecture-based instruction (Crouch et al., 2007; Gok, 2012; Lasry et al., 2008).

The table also shows that the relationship between the covariate and the dependent variable is not significant with 0.779, higher than the probability value of 0.05. This implies the pretest scores of these students had no effect on their posttest scores.

Research question 2: What impact does the Peer Instruction have on the students understanding of the current electricity?

For the purpose of the research question 2, only the Experimental Group (EG) will be discussed below.

Question 1: The question tests the students' understanding of the movement of charges through different materials. There are two types of substance that may either allow charges to flow through them or not. The substances are called conductor, and insulator: conductor allows charge to flow through it while insulator does not. The key difference between conductors and insulators is the mobility of the charges. In a conductor, the individual charges (i.e. the electrons) are highly mobile: in an insulator, each charge is essentially fixed in one location.

Table-2. Students' Correct Answer Responses in Control and Experimental Group.

	Control Group (CG)		Experimental group (EG)	
Question no	Pretest (N = 26)	Posttest (N = 26)	Pretest (N = 26)	Posttest (N = 26)
1	65.4%	62.5%	65%	57.7%
2	26.9%	12.5%	42.3%	19.2
3	27.7%	12.5%	7.7%	11.5%
4	19.2%	25%	57.7%	934.6%
5	519.2%	12.5%	19.2%	42.3%
6	15.4%	6.3%	11.5%	23.1%
7	23.1%	56.3%	30.8%	38.7%
8	3.8%	18.8%	11.5%	15.4%
9	19.2%	18.8%	30.8%	46.2%
10	30.8%	56.3%	0%	26.9%

It is also paramount for the students to know that an electric charge is a form of energy. Given that, the conductor is a material that allows the passage of energy. Therefore, in this case, the conductor is a material that allows the electric energy to pass through it. The insulator is a poor conductor of electrical energy. In an insulator, energy does not easily move from one particle to another.

EG: The table reveals that 65% of the students got the question correctly before the intervention. However, the percentage of the students who got the question correctly dropped to 57% after the intervention. No improvement in the students' understanding due to the PI intervention.

Question 2: The question tests the students' knowledge about the function of fuses. A fuse is a short length of wire designed to melt and separate in the event of excessive current. Fuses are always connected in series with the component(s) to be protected from the excess current, so that when the fuse blows (opens) it will open the entire circuit and stop current through the component(s). Fuse is used to protecting electrical appliances and installation from excessive flow of current. Fuse is not only in electrical appliances but also present at home as a circuit breaker. The most common device in use for excessive current protection in high-current circuits today is the circuit breaker. Circuit breakers are specially designed switches that automatically open to stop current in the event of an excessive current condition. Small circuit breakers, such as those used in residential, commercial and light industrial service are thermally operated.

A residual current circuit breaker (RCCB) can perform different functions. It switches off the mains supply to an appliance when it detects a leakage of current to earth or another circuit. The RCCB measures the current flowing along the live wire, and that is flowing through the neutral wire. Because of the leakage of some of the current (through the person) the live and neutral currents are unequal. The supply is switched off as the RCCB detects this state. It significantly reduces the chances of severe electric shock (Bishop, 2006).This question, therefore, is testing if the students know that circuit breaker is a fuse that protects electrical system.

EG: From the table, 42.3% of the students got the question correctly before the intervention and only 19.2% after the intervention. No improvement in the students' understanding due to the PI intervention.

Question 3: The question tests students' knowledge of Ohm's law and the relationship between the three significant electrical quantities. Ohm's states that the electrical current in a conductor is proportional to the potential difference applied to it provided the temperature remain the same. According to Ohm's law, there is a linear relationship between the voltage drop across a circuit element and the current flowing through it.

Students are expected to be able to use the equation given in the question to define resistance R for any electrical conductor. It is important to understand just what is meant by these quantities. The current (I) is a measure of how many electrons are flowing past a given point during a set amount of time.

Therefore the resistance R is viewed as a constant independent of the voltage and the current. In equation form, Ohm's law is: V = IR. Here, V is the voltage applied across the circuit in volts (V), I is the current flowing through the circuit in units of amperes (A), and R is the resistance of the circuit with units of ohms (Ω). This law gives a linear and perfect relationship between potential difference and current for Ohmic substance only. The plotting of the graph of potential difference against the current for an ohmic substance like silver gives a straight line graph.

For the non- Ohmic substance like a diode, the relationship is not linear. The students are expected to know the difference between any materials that obeys Ohm's law like silver and any others materials that do not obey the law.

EG: From the Table 2, the students' knowledge before and after the intervention is indigent as only 7.7% of the students got the question correctly before the intervention and 11.3% after the intervention. PI improves students' understanding.

Question 4: In electricity, a battery is a device consisting of one or more electrochemical cells that convert stored chemical energy into electrical energy. The dry cell is one of many general types of electrochemical cells. A common dry-cell battery is the zinc-carbon battery, which uses a cell that is sometimes called the Leclanché cell. This cell belongs to the category of a primary cell that once the stored energy is used up cannot be recharged.

The question tests if the students can distinguish between this cell and any other secondary cell. Secondary cells are those batteries that are rechargeable after the stored energy is used up.

EG: Table 2 above shows that the students had an average knowledge of dry cell, because, 57.7% of the students got the question correctly before the intervention. However, the percentage of the students who got the question correctly reduced to 34.6% after the intervention. No improvement in the students' understanding due to the PI intervention.

Question 5: A *fuse* is a small, thin conductor designed to melt and separate into two pieces for the purpose of breaking a circuit in the event of excessive current. Fuses are rated regarding their voltage capacity as well as the current level at which they will blow.

Fuses are rated to blow if the current exceeds a stated amount. The current rating of a fuse is usually the maximum flow that it should withstand on a continuous basis, at the ambient temperature specified by the manufacturer. The ambient temperature refers to the immediate environment of the fuse, not the larger area in which it may be located. Ideally, a fuse should function reliably and indefinitely at its rated maximum amperage, but should blow just as reliably if the current rises by approximately 20% beyond the maximum.

The question tested the students' knowledge of the application of fuse in a real-world situation. The students had been taught that a fuse could not accept any current beyond its rating. In this case, the fuse rating is 5A; the students are expected to know that any current above this value will be unacceptable by the appliance.

EG: Table 2 above shows that only 19.2% of the students got the answer correctly before the peer instruction intervention while 42.3% got it correct after the intervention. There was a considerable improvement in the students' knowledge of the application of the fuse after the intervention. **Question 6:** This is a question that deals with the application of static electricity. The question tested the knowledge of how to discharge static electricity. There was an improvement in the students' understanding.

EG: From Table 2, only 11.5% of the student got the answer correctly before the intervention while 23.1% got the answer correctly after the intervention. This indicates that the students' knowledge on this question is poor. Nevertheless, there was an improvement in the students' knowledge due to the PI intervention.

Question 7: This question tested the students' understanding of the relationships between the fundamental concepts of electrical power transmission. These concepts are Voltage, current, power, and electrical energy. The students should know these concepts when talking about power transmission if not, they will not know the existing relationships. Knowing the relationships will help the students to get the question correctly.

Power is directly proportional to the square of the current multiply by the resistance of the conductor. To, therefore, minimize power loss due to heat, power should be transmitted in high voltage and low current. Power loses= current^2 x resistance.

Also, the low current in transmission lines restricts their power carrying capacity, which equals the product of current and voltage across a transmission line: power = voltage x current.

EG: From Table 1, 30.8% of the students got the question correctly before the Peer Instruction intervention and 38.7% after the intervention. The students' knowledge of this question is inadequate; nevertheless, the result shows an improvement of students' knowledge due to the intervention.

Question 8: The students have been taught two types of electrical connection which area parallel and series connection. Electrical connection in the home could only fall into any of these two categories. The question, therefore, tested students' understanding of differences between series and parallel connection and the application to the electrical connection at home.

In a parallel circuit, there are several pathways for electron flow between the terminals of the battery. It is a connection with a set of elements which are directly connected by wire at both ends. Parallel connection carries the same voltage but different current. In a series circuit, there is only a single pathway for electron flow between the terminals of the battery. Each resistor in series has the same current but the same voltage.

EG: From Table 2, only 11.5% of the student got the correct answer before the intervention while 15.4% got the answer correctly after the intervention. The students had poor knowledge of this question both before and after the intervention. Nevertheless, PI intervention had a small effect on the students' understanding.

Question 9: The resistance of a conductor increases as the temperature increase. Resistance is directly proportional to the temperature. When temperature increases the amplitude of vibration of atoms also increase leading to more collisions between atoms and electrons. In an insulator, however, the situation is slightly different.

Few free electrons hardly can permit the flow of any current. Almost all the electrons are strongly bound to their particular atom. Heating an insulating material causes vibration of the atoms, and if the heat is sufficient enough, the atoms vibrate violently to liberate more electrons from the atom. The freed electrons become carriers of electric current. Therefore, the resistance of an insulator falls at high temperatures.

A positive temperature coefficient happens in a material where the resistance increases with an increase in temperature. A material where resistance falls with an increase in temperature is said to have a negative temperature coefficient. Conductors have a positive temperature coefficient, while insulators have a negative temperature coefficient.

This question tests the students' understanding of the concept of resistance and also the relationship between temperature and resistance. The students' response to the question shows poor students' understanding.

EG: Table 2 shows that 30.8% of the students got the question correctly before the peer instruction intervention and 46.2% after the intervention. It shows improvement in students' knowledge due to peer instruction intervention.

Question 10: A capacitor stores energy in the form of an electric field while the inductor is a coil which stores energy in the magnetic field. Capacitor and inductor are two passive and linear elements. Unlike the resistor which dissipates energy, ideal capacitors and inductors store energy rather than dissipating it.

The question examined the students' knowledge about the uses of capacitor and inductor. Results indicate that the students' understanding of the capacitor and inductor was poor.

EG: Table 2 indicates that no single student got the correct answer to this question before the peer instruction intervention (0%). However, 26.9% of the students got the answer correctly after the PI intervention. Obviously, the PI intervention helped to improve the students' knowledge about the capacitor and inductor, yet students' knowledge is inadequate.

The PIDAQ contains structured, and unstructured, open-ended questions to get students ideas of their personal experience about the PI. 85% of the students agreed they had many misconceptions in current electricity which they were able to overcome through PI.

According to these students, the misconceptions they overcame through the PI are the following: how insulator works, resistor and resistance, electrical circuit. Many questions asked by the students during the PI interactive classes reveals several misconceptions held by the students, in particular on the resistance. Confirming the personal experience that took place during the interactive class in PI, McDermott and Shaffer (1993) said resistance is one of the misunderstood concepts in electricity.

Given the analysis in Table 1 above there is no significant difference between students taught with the PI and the traditional lecture method.

This finding is providing an answer to the research question 1 of the study. From the Table 2 and the subsequent analysis, PI improve the students understanding of current electricity. Specifically, PI impact students' understanding of the Ohm's law, the relationship between resistance and temperature, capacitor, electrical power, and much more.

The finding provides an answer to the research question 2. This finding consistent with Crouch and Mazur (2001); Fagen and Mazur (2003) that PI has the potential of improving the conceptual and problem-solving skill understanding of science students. The outcome of this study is supported by McDermott and Shaffer (1993) that students had problems recognizing parallel branches when they were not connected directly to the battery. Besides, the PI helps to identify and get rid of misconceptions held by the students in electricity as supported by Porter, Lee, Simon, and Zingaro (2011) and Crouch et al. (2007). The next focus is the summary and the major findings of the study.

8. Summary of the Findings and Recommendations

The findings of this study are given below.

There was no significant difference in the academic performance of the students who attended the PI class and those students in the lecture method. The PI impacts students' understanding of current electricity and help identifies and solved the problem of misconception.

The PI affects positively in the relationship between resistance and temperature, Ohm's law, capacitor, electrical power, and much more. The misconception students had in electricity is supported by Engelhardt and Beichner (2004) and McDermott and Shaffer (1993).

However, the opportunity the students had to involve in dialogical argumentation may have helped identified and solve the problem of misconceptions. Given the above findings, the following are recommended:

- The dialogical argumentation instruction should always be used along with the PI to strengthen its power in solving the problem of students' misconceptions in sciences.
- Researchers in Nigeria and Africa countries should do more study on the PI.
- More research should be carried out using different schools but still on current electricity to find out the veracity of these findings.

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