

## Enhancing Students' Achievement in Senior Secondary One: Concepts of Work, Energy and Power through Polya's Problem-Solving Instructional Strategy in Jos South, Nigeria

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### Abstract

This study focused on enhancing students' achievement in senior secondary one concepts of work, energy and power through Polya's problem-solving instructional strategy (PPSIS) in Jos South, Nigeria. The study premised on the not too impressive and fluctuating achievement of students in Physics and the perceived difficulty of Physics concepts by secondary school students. It adopted the non-equivalent control group pre-test, post-test quasi-experimental research design. A sample of 90 senior secondary one (SS I) students from two co-educational secondary schools was used for the study. A 25-item multiple-choice Work, Energy and Power Achievement Test (WEPAT) was used as instrument to test students on the effectiveness of PPSIS on their achievement in concepts of work, energy and power. The reliability coefficient of WEPAT was computed as 0.72, using Kuder-Richardson formula 20. Three research questions were raised and answered using mean, while three hypotheses were formulated and tested at  $\alpha = 0.05$  using Analysis of Variance (ANOVA). Findings revealed, amongst others, that there was no significant difference between students' achievement when students were taught concepts of work, energy and power using PPSIS and lecture method (LM); furthermore, there was no significant difference between male and female students' achievement when they were exposed to the teaching using PPSIS. Based on the findings, recommendations were made tailored towards encouraging Physics teachers to adopt PPSIS in teaching concepts of work, energy and power, since the method has been found to enhance students' achievement in those concepts and in teaching other Physics concepts because it is gender-friendly.

**Keywords:** *Instructional Strategy, Problem-solving, Physics Concepts, Students' Achievement, Students' Gender, Nigeria*

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### **Background to the Study**

Physics is one of the two core physical sciences (Chemistry and Physics) that is concerned mainly with the study of matter and energy. It has great importance to the development of a nation as it provides the fundamental scientific knowledge needed for technological advancement which drives the economy of nations. An instance is in the field of medicine where the knowledge of Physics led to the invention of devices such as the x-ray machines used in hospitals for the detection of fractures in bones and for cancer cure. In communications sector, the production of gadgets such as the television, radio, computer and mobile phones has also been made possible as a result of the principles, laws and theories in Physics. In the area of agriculture, the production and working of machines such as tractors, incubators, planters and harvesters is made possible also due to principles, laws and theories of Physics. Despite the importance of Physics to national development and the efforts of the government of Nigeria towards enhancing science and technology by establishing more institutions of learning, students' achievement in Physics at the secondary school level have not been too impressive and have been fluctuating over the past years. Josiah and Larina (2015), Josiah, Mallo and Inyang (2019) opined that the lecture method of instruction used by most Physics teachers does not promote or foster critical thinking and students' participation. The studies revealed the persistent use of expository instructional strategies, which includes the lecture method, by teachers in Nigeria which do not lead to high students' achievement. There are instructional methods, such as Polya's problem-solving instructional strategy (PPSIS) that foster active participation of students in the teaching-learning process and promote their critical thinking. Problem solving is a cognitive process in which students critically think the problem through.

Inah and Anditung (2021), submitted that the PPSIS enables students to identify problems by themselves and solve such problems using systematically appropriate skills. The duo opined that problem-solving provides the student with the highest form of learning since the student is able to further define new ideas as he learns using PPSIS. A synergy of the views of Woolfolk and Dhillon on PPSIS as cited in Selcuk, Caliskan, and Erol (2008) explains PPSIS as an instructional strategy in which students use to solve problems by exploring the solution path to reach a goal from given data; and as they do so, they formulate new results and explore new frontiers beyond the simple application of previously learned rules to arrive at solutions. While the Physics teacher plays the role of a facilitator in this method, the students find out by themselves whether a problem exists; if it does, they first create an exact statement of the problem; next, they identify information, data, and learning goals, creating a working plan. Specific outcomes in the PPSIS are effective problem-solving skills, self-directed, lifelong learning skills, and effective collaborations by the students. Studies conducted by Olaniyan and Govender (2018), Phuntsho and Dema (2019) indicate that PPSIS improves the achievement of students in current electricity and Mathematics, respectively.

The PPSIS as suggested by George Polya, the inventor of problem solving, has four techniques which In'am (2014), Phuntsho and Dema (2019), outlined in sequential order as a) Understanding a problem; b) Devising the plan to overcome the problem (workable plan); c) Implementing the plan; and d) Looking back on the solution process. The first technique to

solving a Physics problem in PPSIS requires the student to understand the problem. The problem may be a given task by the teacher. This, the student will have to do by understanding what the unknown (to be solved for) concept in the problem is, and the concepts/information provided in the problem that will help the student solve for the unknown concept. The student is needed to further find out if there is any condition required to be satisfied in order to successfully solve the problem; and ask himself whether the condition to help in finding out the unknown concept is sufficient or not. The student is also required to proceed to draw a figure depicting the problem (if any) for clarity, introduce suitable and acceptable notation(s), separate the various parts of the condition and write them down.

The second technique to solving a Physics problem in PPSIS requires the student to devise a workable plan by relating the concepts/information provided in the problem with the unknown concept to be determined. That is, the student needs to find out what connects the concepts/information provided in the problem and the unknown concept to be solved for. The student can consider auxiliary problems if an immediate link cannot be readily obtained. Phuntsho and Dema (2019) were of the view that a student best learns the skill at choosing an appropriate plan by solving many problems. The problems include those the student has seen before, same problems in a slightly different forms, and laws or principles that could facilitate the solution.

The third technique to solving a Physics problem in PPSIS requires the student to implement the devised plan that will lead to the solution, carefully checking each step to ensure clarity and precision. The student can change the plan to another one, if it does not work. The student will eventually, through constant practice, find that choosing a plan to solve problems on a particular topic a less difficult thing to do. The fourth technique to solving a Physics problem in PPSIS requires the student to evaluate the problem they have solved. The student goes through the work all over again, looking back and checking the correctness or otherwise in each step that led to the solution. The student can reflect on whether there are different ways of approaching the problem that will lead to the required solution.

For fear of potentially taking over students' cognitive reasoning, Jacobs, Martin, Ambrose and Philipp (2014), cautioned teachers to avoid interrupting the students when they are learning under PPSIS, manipulating the tools for the students, and asking students close-ended questions. As a facilitator in the PPSIS, the teacher needs to wait until students finish solving a given task before intervening. When a student supplies the wrong answer to a problem, the teacher needs to render all or any of the following assistance: a) Encourage the student to try other methods of solving the problem; b) Make certain that the student understands the given problem; c) Thoroughly go through the submission of the student so as to ascertain where the student got it wrong, with a view to asking the student leading questions towards understanding; d) Change the problem to a similar, but simpler one, for the student to understand.

When a student solves a given problem correctly, the teacher needs to buttress the student's understanding by asking questions that may broaden the student's understanding towards

further solving similar and complex problems. Studies on problem solving show that students' achievement can be affected when they are taught with PPSIS. In this study, students' performance in a subject was operationally defined as their achievement.

Studies conducted by Selcuk, Caliskan, and Erol (2008), Caliskan, Selcuk and Erol (2010), in Turkey revealed that students taught Physics using PPSIS achieved significantly higher than those taught with the lecture method. In Nigeria, the findings of Olaniyan, Omosewo and Nwankwo (2015), from a study on effect of Polya problem-solving model on senior secondary school students' achievement showed that students taught current electricity, an aspect of Physics, using PPSIS achieved higher than their counterparts who were taught the same concept using lecture method. Also in Nigeria, Usman and Sule's (2017) study revealed that students taught Physics with problem-solving strategy significantly achieved higher than their counterparts who were taught using lecture method. In a similar study undertaken in Nigeria, although in Geometry (an aspect of Mathematics), Inah and Anditung (2021) also found out that students taught using PPSIS achieved significantly higher than those taught with the lecture method.

Research work on students' achievement based on gender, when they are exposed to PPSIS, have also been undertaken. For instance, Olaniyan, Omosewo and Nwankwo (2015) conducted a study and found no significant difference between the achievement of male and female students when they were taught current electricity. Similarly, Usman and Sule's (2017), Inah and Anditung's (2021) studies revealed no significant difference between the achievements of male and female students who were taught Physics and Geometry, respectively. Other gender-based researches, such as those of Alao and Abubakar (2010), Josiah (2019), Josiah and Okonkwo (2020), Josiah and Shedow (2020), Josiah, Usman, Mallo, Gwamna and Inyang (2020), Josiah and Mankilik (2021) also revealed no significant disparity in the achievement of male and female students. However, there is evidence of significant difference in the achievement of male and female students in some gender studies (Trisma and Josiah, 2008; Samuel and Peter, 2013; Mankilik and Mallo, 2020). Such studies revealed that female students achieved significantly higher in Physics than male students or vice versa.

Although studies such as those of Selcuk, Caliskan, and Erol (2008), Caliskan, Selcuk and Erol (2010), Olaniyan, Omosewo and Nwankwo (2015), Usman and Sule (2017), Inah and Anditung (2021) were carried out on PPSIS, none of such studies, to the best of the knowledge of the researchers, were undertaken in Jos South, Plateau state, Nigeria. Jos South is a local government area in Plateau State, Nigeria. This study was, therefore, conducted to ascertain if the use of PPSIS in secondary schools in Jos South, Plateau state, Nigeria would achieve the following specific objectives: ascertain the pre-test mean achievement scores of secondary school students taught work, energy and power using Polya's problem-solving instructional strategy (PPSIS) and lecture method (LM); determine the post-test mean achievement scores of secondary school students in concepts of work, energy and power exposed to PPSIS and LM; find out the post-test mean achievement scores of male and female secondary school students in concepts of work, energy and power exposed to PPSIS; determine whether the

difference between the pre-test achievements of secondary school students taught concepts of work, energy and power using PPSIS and LM is significant; ascertain whether the difference between the post-test achievements of secondary school students taught concepts of work, energy and power using PPSIS and LM is significant; find out whether the difference between the post-test achievements of secondary school male and female students taught concepts of work, energy and power using PPSIS is significant.

### **Statement of the Problem**

The fact that Physics plays a key role in most sectors and is important to the development of every nation places a demand on every nation not to overlook education. The situation of students' achievement in Physics examinations in Nigeria such as Senior School Certificate Examination (SSCE) organized by West Africa Examinations Council (WAEC) and National Examinations Council (NECO), however, has either not been encouraging or has been fluctuating over the years (Bello, 2011; Josiah, 2012; Josiah and Gana, 2019; Josiah and Shedow, 2020; Josiah and Pwol, 2020; Josiah, Usman, Mallo, Gwamna and Inyang, 2020). Physics is a subject which serves as a major instrument for national development even though it has, on the other hand, suffered negatively in terms of students' learning and achievement. Josiah (2012), Josiah and Gana (2019), Josiah and Pwol (2020) adduced the problem to many factors which includes the expository methods of instruction (lecture method inclusive) used by many Physics teachers in schools in Nigeria. Other factors include the perceived difficulty by students and abstract nature of most Physics concepts such as work, energy and power. Inyang and Josiah (2016) noted that most Physics concepts, which can be either concrete or abstract, are perceived difficult by students. Saglam-Arslan and Kurnaz (2011), identified energy as an abstract and difficult concept to learn; and in their study on students' perceived difficult concepts in Physics, Bello, Opaleye and Olatunde (2018) found out that students perceive work, energy and power as difficult.

The lecture method hardly encourages students to critically think through problems using their internal mental processes. This is more so as it is not centred on learners as constructors of knowledge using their own cognitive abilities. In contrast to the lecture method of instruction, Polya's problem-solving instructional strategy (PPSIS), also referred to as problem-solving method of instruction, is learner-centred and encourages students to actively participate in the teaching-learning process, to critically think and learn skills as they solve problems. This study, therefore, set out to ascertain if the use of PPSIS would enhance students' achievement in the concepts of work, energy and power in Jos South, Nigeria. Furthermore, due to the role Physics plays in national development and topical contemporary gender issues, this study investigated the impact of the PPSIS on male and female students' achievement in the concepts of work, energy and power. Jos South local government area is one of the 17 local government areas in Plateau state, Nigeria. In the context of this study, it has been delineated as Jos South.

### **Research Questions**

The following questions were raised to guide the researchers during the study:

1. What are the pre-test mean achievement scores of senior secondary one (SS I) students taught work, energy and power using Polya's problem-solving instructional strategy (PPSIS) and lecture method (LM)?

2. To what extent does the post-test mean achievement score of SS I students taught work, energy and power using PPSIS differ from that of their counterparts who were taught using LM?
3. What is the difference between the post-test mean achievement scores of SS I male and female students who were taught work, energy and power using PPSIS?

### **Hypotheses**

The following null hypotheses were formulated and statistically tested at 0.05 level of significance:

1. There is no significant difference between the pre-test achievements of SS I students who were taught work, energy and power using PPSIS and their counterparts who were taught using LM.
2. There is no significant difference between the post-test achievements of SS I students who were taught work, energy and power using PPSIS and those who were taught using LM.
3. There is no significant difference between the post-test achievements of SS I male and female students who were taught work, energy and power using PPSIS.

### **Methodology**

The study adopted the non-equivalent control group pre-test, post-test quasi-experimental research design because intact classes were used. The lottery method of the simple random sampling technique was used to obtain two sample co-educational secondary schools for the study. One of the two schools was randomly assigned the experimental group while the second was assigned the control group. A total intact sample of 90 SS I students (57 male and 33 female) offering Physics from the two sampled co-educational secondary schools was used to gather data for the study. The experimental group was made up of 31 male and 19 female students, while the control group comprised 26 male and 14 female students. The study was carried out using SS I students because the concepts of work, energy and power is in the SS I senior secondary school Physics curriculum (in use in most schools) as provided by Nigerian Educational Research and Development Council (2008).

The instrument used in the study was a 25-item multiple-choice Work, Energy and Power Achievement Test (WEPAT) whose reliability coefficient was computed as 0.72 using the Kuder-Richardson formula 20 method. The WEPAT was developed by the researchers using test blueprint, questions on the concepts of work, energy and power from past West African Senior School Certificate Examination (WASSCE) Physics and National Examinations Council (NECO) Senior School Certificate Examination (SSCE) Physics question papers. This instrument enabled the researchers to measure students' achievement in the concepts of work, energy and power before and after treatment. The instrument was initially given to three experts in the University of Jos for content validity.

The WEPAT was administered as pre-test to all the sample in the two groups by the researchers, before treatment of PPSIS on the experimental group. The instrument was administered a week before the treatment commenced. The pre-test was carried out so as to

determine the achievement of the sample students in the concepts of work, energy and power before treatment. Thereafter, treatment was carried out on the experimental group for a period of four weeks on the concepts of work, energy and power. The control group was merely engaged on the same concepts of work, energy and power by being taught using the LM during the same period of four weeks that the experimental group was treated. After the four weeks treatment, in the fifth week, the WEPAT was re-administered as post-test to all the students in both the experimental and control groups, after reshuffling the items. The post-test was administered so as to determine whether PPSIS had an effect on students' achievement, and whether the experimental and control groups differ in their mean achievement scores in the concepts of work, energy and power. The mean, a descriptive statistics, was used to answer all the three research questions that were raised; while Analysis of Variance (ANOVA) was employed to test all the three formulated hypotheses.

## Results

### Research Question One

What are the pre-test mean achievement scores of senior secondary one (SS I) students taught work, energy and power using Polya's problem-solving instructional strategy (PPSIS) and lecture method (LM)?

The summary of the results of data analysis on research question one is presented in Table 1.

**Table 1:** Pre-test Mean Achievement Scores of Students in the Experimental and Control Groups

Group	N	Mean	SD	MD
Experimental	50	11.85	0.29	0.16
Control	40	11.69	0.33	

Table 1 revealed a mean achievement score of 11.85 for the experimental group and 11.69 for the control group. The standard deviations were 0.29 and 0.33 respectively. These results yielded the mean difference of 0.16 as the difference between the achievements of the two groups. The results indicate no much difference between the mean achievement scores of students in the experimental and control groups before exposure to the treatment using PPSIS. That is, since none of the groups was yet to be exposed to treatment, their mean achievement scores did not show much difference.

### Research Question Two

To what extent does the post-test mean achievement score of SS I students taught work, energy and power using PPSIS differ from that of their counterparts who were taught using LM?

The summary of the results of data analysis on research question two is as presented in Table 2.

**Table 2:** Post-test Mean Achievement Scores of Students in the Experimental and Control Groups

Group	N	Mean	SD	MD
Experimental	50	14.58	1.33	1.83
Control	40	12.75	0.89	

Table 2 showed post-test mean achievement scores of 14.58 and 12.75 for the experimental and control groups respectively. The result shows that SS I students who were taught work, energy and power using PPSIS achieved higher than those taught using LM. The higher mean score for students in the experimental group could be attributed to the effect of the treatment of PPSIS the students were exposure to before the administration of the post-test.

### Research Question Three

What is the difference between the post-test mean achievement scores of SS I male and female students who were taught work, energy and power using PPSIS?

The summary of the results of data analysis on research question three is presented in Table 3.

**Table 3:** Post-test Mean Achievement Scores of Male and Female Students in Experimental Group

Gender	N	Mean	SD	MD
Male	31	14.77	0.84	2.35
Female	19	12.42	0.96	

The findings in Table 3 revealed that male students in the experimental group had a post-test mean achievement score of 14.77 as against 12.42 for their female counterpart. The results provided the mean difference of 2.35 in favour of male students. This implies that even though both students were exposed to the treatment of teaching using PPSIS, the male students achieved higher in the concepts of work, energy and power than the female students.

### Hypothesis One

There is no significant difference between the pre-test achievements of SS I students who were taught work, energy and power using PPSIS and their counterparts who were taught using LM.

The summary of the results of data analysis on hypothesis one is presented in Table 4.

**Table 4:** Analysis of Variance (ANOVA) of Pre-test Achievement of Students in the Experimental and Control Groups

Source of Variation	Df	SS	MS	F-cal.	F-tab	Decision
Between	1	0.44	0.44			Retain H <sub>0</sub>
Within	88	1259.12	14.31	0.03	3.92	
<b>Total</b>	<b>89</b>	<b>1259.56</b>	<b>14.15</b>			

P < 0.05



From table 4, since F-ratio (0.03) calculated was less than F-ratio (3.92) from tables at 0.05 level of significance and F(1,88) degree of freedom, the hypothesis was retained. The implication is that there was no significant difference between the pre-test achievements of SS I students in the concepts of work, energy and power in the experimental and control groups.

### Hypothesis Two

There is no significant difference between the post-test achievements of SS I students who were taught work, energy and power using PPSIS and those who were taught using LM.

Table 5 provides the summary of the results of data analysis on hypothesis two.

**Table 5:** Analysis of Variance (ANOVA) of Post-test Achievement of Students in the Experimental and Control Groups

Source of Variation	df	SS	MS	F-cal.	F-tab	Decision
Between	1	27.88	27.88			Retain H <sub>0</sub>
Within	88	1902.08	21.61	1.29	3.92	
<b>Total</b>	<b>89</b>	<b>1929.96</b>	<b>21.68</b>			

P < 0.05

From Table 5, since F-ratio (1.29) calculated was less than F-ratio (3.92) from tables at 0.05 level of significance and F(1,88) degree of freedom, the hypothesis was retained. This implies that there was no significant difference between the post-test achievements of SS I students in the concepts of work, energy and power in the experimental and control groups.

### Hypothesis Three

There is no significant difference between the post-test achievements of SS I male and female students who were taught work, energy and power using PPSIS.

The summary of the results of data analysis on hypothesis three were presented in Table 6.

**Table 6:** Analysis of Variance (ANOVA) of Post-test Achievement of Male and Female Students in the Experimental Group

Source of Variation	df	SS	MS	F-cal.	F-tab	Decision
Between	1	68.86	68.86			Retain H <sub>0</sub>
Within	48	834.82	17.39	3.96	4.00	
<b>Total</b>	<b>49</b>	<b>903.68</b>	<b>18.44</b>			

P < 0.05

From Table 6, since F-ratio (3.96) calculated was less than F-ratio (4.00) from table at 0.05 level of significance and F(1,48) degree of freedom, the hypothesis failed to be rejected. The implication is that there was no significant difference between the post-test achievements of SS I male and female students both exposed to PPSIS when taught the concepts of work, energy and power.

## **Discussion**

From Table 1, there was no much difference between the mean achievement scores of students who were taught the concepts of work, energy and power using PPSIS and those taught the same concepts using LM, even though the difference was in favour of students who were exposed to PPSIS. The test analysis from Table 4 further indicates that no significant difference exist between the achievements of the students in the two groups (experimental and control) before treatment commenced. This result implies that the average entry behaviours of the students in the two groups, in terms of knowledge acquisition, information manipulation and reasoning ability the cognitive ability were equivalent, prior to the study.

Students who were taught work, energy and power using the intervention (PPSIS) achieved higher than those taught using the LM (Table 2). The higher mean achievement score for students in the experimental group could be attributed to the effect of the treatment of PPSIS which the students were exposure to before the administration of the post-test. However, results from Table 5 revealed no significant difference between the achievements of the students in the two groups, although the students in the experimental group achieved higher in the WEPAT than those in the control group. In their study on the use of PPSIS to teach current electricity in secondary schools, Olaniyan, Omosewo and Nwankwo (2015), found out that there was no significant difference between the achievements of students exposed to PPSIS and those exposed to LM. That finding is contradicted by the finding of this study. The lack of significant difference between the achievements of the students in the two groups even after the intervention, could be adduced to varying factors which include students' poor attitude to learning Physics revealed by Josiah (2004), their fear for calculations, complaints about numerous formulae to memorize, their lack of interest in Physics as revealed by Bello, Opaleye and Olatunde (2018), their poor mathematical skills, quality of teaching and abstract nature of Physics concepts as mentioned by Bray and Williams (2020).

From Table 3, even though both students were exposed to the treatment of teaching using PPSIS, the male students achieved higher in the concepts of work, energy and power than their female counterparts. However, Table 6 shows that no significant difference exist between the achievements of male and female students both exposed to PPSIS when learning the taught concepts. This finding concurs with those of Olaniyan, Omosewo and Nwankwo (2015), Usman and Sule (2017), that there is no significant difference between the achievements of male and female students who were exposed to PPSIS.

## **Conclusion**

This study investigated the effects of Polya's problem-solving instructional strategy on students' achievement in the concepts of work, energy and power in Physics. Results from the study indicates that the strategy enhances students' achievement in those concepts and is not gender-biased.

## **Recommendations**

Based on the findings of this study, the researchers recommended that:

1. Polya's problem-solving instructional strategy should be used by teachers in teaching the concepts of work, energy and power in Physics; if properly implemented it can go

a long way in improving students' achievement in those concepts which are abstract and are perceived as difficult by students.

2. Polya's problem-solving instructional strategy should be adopted by teachers in teaching other Physics concepts as it has been found to be gender-friendly and has the capacity to bridge gender disparity.

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