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USING PARTICIPATORY PROBLEM SOLVING APPROACH TO ENHANCE STUDENTS' ACHIEVEMENT IN DERIVATIVE OF A FUNCTION IN WA SHS

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ABSTRACT

The purpose of the study was to investigate the influence of using Participatory Problem Solving Approach (PPSA) on students' achievement in differentiation word problems. To achieve this, one major question was answered: what is the impact of Participatory Problems Solving Approach on students' achievement in differentiation word problem? The researcher used non-equivalent control groups' pre-test post-test quasi-experimental design for the study. A sample of 80 SHS3 students was drawn from Wa Senior High School in the Upper West Region. Two experimental groups namely: participatory problem solving group (treatment group) and a Control Group were 40 students each constituted in the two classes. Data were collected using Mathematics Achievement Test validated by experts and found to have a reliability index of 0.947. Data analyses were done using independent samples t-test and paired samples t-test. The results indicated that Participatory problem Solving Approach enhances students' achievement in differentiation word problems. The researchers concluded that applying participatory problem solving approach in the classroom is capable of enhancing mathematics achievement of both high and low *ability students. The researchers recommended that Mathematics teachers should be encouraged to integrate Participatory Problem Solving Approach in their instructional processes. Mathematics students should apply PPSA in their learning of mathematics.*

Keywords: *Participatory Problem Solving Approach, Achievement, Differentiation word problems, problem solving*

Introduction

Problem solving in the mathematics curriculum is not a stand-alone topic or sub-topic to be taught or learned on its own but integrated in all topics and sub-topics stated by the mathematics curriculum (Sarfo, Eshun, Elen and Impraim, 2014; Nabie, Akayuure and Sofo, 2013). Problem solving is a methodological pillar to mathematics as it develops learners' skills in analysis, comprehension, reasoning, and application (Lorenzo, Eloisa, and Ana, 2013) and requires high quality instructions (Robert, 2017).

One tool invented for investigating and solving problems is Calculus. According to Heinkel (2014), Calculus, the study of change, was invented by Isaac Newton and Gottfried Wilhelm Leibniz around 1687. Leibniz and Newton arrived at the discipline independently and both are given credit for developing calculus. Calculus has widespread applications in science, economics, and engineering and can solve many problems for which algebra alone is insufficient. A course in calculus is a gateway to mathematical analysis.

Two fundamental concepts underpin the study of Calculus namely: the differentiation and the integration. Differentiation is one of the fundamental concepts of Calculus. According to Stewart (2003), differentiation is the process of finding the derivative of a function. The derivative, also referred to as the derived function, enables us to determine how one quantity changes with regard to another. The derivative can be interpreted as slope or gradient, instantaneous velocity, marginal revenue, or marginal profit.

Derivatives are applied in many fields of problem solving today. According Heinkel (2014) derivatives are applied in the following areas: A graphics artist uses calculus for three-dimensional models, movies or video games; exact length of power cable; the amount of materials necessary for construction, the growth of bacteria culture, measuring the instantaneous rate of change, predicting the outcome of chemical reactions, and in solving problems involving minima and maxima among others (Heinkel, 2014).

By the curriculum structure, Calculus is to be studied in the third year of the SHS programme. The Ministry of Education (2010), stated that students' ability to understand and use the two fundamental concepts of calculus and use them skillfully in problem solving is vital for living and working in the scientific world. To enable students to meaningfully learn the derivative, teachers must engage their students in solving all the types of problems on derivatives delineated by the curriculum. There are four types of problems involving derivatives in the curriculum namely: routine, non-routine, algebraic, and word problems. The curriculum requires teachers to integrate problem solving activities in every lesson they teach to develop students' competencies and reasoning skills in solving all these categories of problems.

Although problem solving is the hub of mathematics education in Ghana, research consistently indicates poor progress of Ghanaian students in mathematics problem solving activities (Robert, 2017). Assessments on Ghanaian students' achievement in mathematics and science subjects clearly point out that the students performed poorly because of their weak word problem solving abilities and their inability to comprehend the language of the test (Kushwaha, 2014). Also, the Chief Examiner's report for West Africa Senior Secondary Certificate Examination

[WASSCE] (2017, 2018, 2019), consistently indicate that students have difficulty in translating word problems into mathematical sentences. The reports point out that, students who answer word problems usually perform poorly because they lack fundamental mathematical knowledge that limits their problem solving ability. The poor achievements of students and their inability to solve mathematical problems as well as to comprehend the language when dealing with word problems probable attributed to the teaching approach or methods used by teachers.

Although there are many methods of teaching mathematics, most Ghanaian mathematics teachers continue to use the teacher-centered method (Ampadu, 2014; Padmavathy and Mareesh, 2013) in their classrooms even though the curriculum emphasises student-centered learning (Ampadu, 2014). Teacher-centered method makes the students passive learners which in turn makes the student ineffective in mathematical analysis and logical reasoning. This instructional method also creates difficulties in learning that leads to poor achievements and poor attitudes towards mathematics among the students. In teacher-centered methods, teachers concentrate primarily on getting answers making students rely on them to decide the validity of their answers. Students from this background tend to view mathematics as a series of arbitrary rules, emanating from the teacher. The follow-the-rules, computation-dominated, answer oriented view of mathematics resulting from teacher-centered approaches is a gross misrepresentation of what mathematics is really about (Saleh and Abdul Rahaman, 2016; Abonyi and Umeh, 2014). This traditional approach cannot be exciting to learners. Few learners are good at learning rules and strive to get good grades but are not necessarily the thinkers in the classroom.

In recent times, mathematics teachers are obliged to assist students to comprehend and develop confidence in solving mathematical word problems including derivative word problems (Perveen, 2010). Teachers are to give appropriate assistance to students in a skillful way to enable them develop conceptual understanding of what they are to study (Hmelo-Silver, 2013). They may make no progress in their conceptual understanding, if students are left alone. No mathematical task will be left for them to do, if they are aided too much. In the conventional mode, the student tends to be a passive listener and writes down concepts they do not understand (Mwelese and Wanjala, 2014). They cannot easily recall when learners study this way. Therefore, assistance to students should not be too much or too little. In this way, the student will have a moderate task to perform (Polya, 1957).

Kushwaha(2014) advised teachers to enhance quality of instruction by shifting from teacher-centered approach to student-centered approach in their lesson presentations. They are to adopt teaching methods that focus on increasing students' problem solving abilities, as well as their abilities to reason, communicate, connect ideas and shift among representations of mathematical concepts and ideas. Participatory Problem Solving Approach (PPSA) is one student-centered approach that allows learners to construct their own knowledge. The Participatory Problem Solving Approach (PPSA) strategy organizes mathematics instruction around problem solving activities and allows students more opportunities to think critically, present their own creative ideas, and communicate with peers mathematically (Isik, Kaplan, Konyalioglu, Guler and Kar, 2011). Participatory Problem Solving Approach (PPSA) in the mathematics classroom concentrates on problem-solving and conceptual understanding rather than on computational drill. It also promotes students' confidence in their own mathematical abilities (Cruz and Lapinid, 2014; Ali, Hukamdad, Akter and Khan, 2010; Andam, Atteh and Obeng-Denteh, 2016). This instructional approach is not dominated by the teachers' or the textbooks' way- to solve a problem that characterizes the traditional method, but locates learning in a classroom community in which members discover and solve mathematics problems together. In this community, learners engage in collaboration, cooperation, dialogue and work in groups (Abonyi and Umeh, 2014; Saleh and Abdul Rahaman, 2016; Assuah and Ayebo, 2015; Nabie, Akayuure & Sofo, 2013; Nabie, 2009). Opportunities are given to members of the learning community to express their ideas during the lesson. The teacher gives open-ended questions and tasks that afford multiple solutions to solving the problems.

Students' who participate in PPSA environments have greater conditions to learn mathematical processes associated with communication, representation, modeling and reasoning (Schoenfeld, 2016).

Studies that use PPSA as an instructional approach show a quantifiable improvement on students achievement in mathematics (Iji, Emiakwu, and Utubaku, 2015; Abdul Kadir, Abdullah, Anthony, Mohd Salleh, and Kamarulzaman, 2016; Saleh and Rahaman, 2016; Wen-Haw, 2013, Veneranda, 2014). The study of Ajai, Imoko, and O'kwu (2013) on the effect of Participatory Problem Solving (PPSA) on Wa Senior High School students' achievement in algebra revealed that students taught using Participatory Problem Solving achieve more than those taught using the conventional method. PPSA methods play significant roles in developing students' attitudes towards mathematics and achievement, and its effective use encourages cooperative learning among students, problem solving skills enhance their effective mathematical confidence in the classroom (Abdullah, Abidin, and Ali, 2015; Adu, Assuah and Aseidu-Addo, 2015; Ajai, and Imoko, 2015). However, limited studies if any explored PPSA in Ghana. Therefore, Participatory Problem Solving Approach (PPSA) is designed to improve Wa Senior High School students' achievement in derivative word problems.

Research Question

What is the difference on students' achievement in solving word problem on derivatives/differentiation of functions using PPSA and TM?

In order to answer research question, these null and alternative hypotheses were formulated.

H_0: There is no statistically significant difference in the mean achievement scores of students taught differentiation word problems using Participatory Problem Solving Approach (PPSA) and those taught using Traditional Method (TM).
H_1: There is statistically significant difference in the mean achievement scores of students taught derivative word problems using Participatory Problem Solving Approach (PPSA) and those taught using Traditional Method (TM).

Methods

Research Design

This study adopted a pre-test, post-test non-randomized control group design in a quasi-experimental setting (intact classes) (Field, 2012). This design was adopted because the independent variable, assessment mode (paper-pencil) was manipulated while the sample of the study was not randomly selected as the classes were used as intact groups. It involves students-centred participation in a dynamic research process, while monitoring and evaluating the effects of the researcher's action with the aim of improving practice.

Participants

In this study, two classes out of fifteen classes in the Wa **S**HS were selected, 3S1and 3S2, were chosen as the sample population for the study with 3S1 taken as the Treatment group and 3S2 the Control group. These classes were sampled because they all had the same content knowledge base and they were treating the same topic which could provide information to answer research the question. The sample classes also had the same entry behaviors appropriately for the study. Each class Sample was forty (40). Therefore, two classes summed up to eighty (80) students of 3S1 and 3S2. Sampling procedures for the study were a combination of convenience and purposive sampling techniques (Cohen, Manion and Morrison, 2011). Convenience sampling technique was, therefore, used to select the region and the school because of proximity, easy access and special characteristics of the schools in facilitating the purpose of the research (Field, 2009). Purposive (non-probability) sampling was used to select 3S1 and 3S2 classes for the study. There were science classes and each class students were 40.

Research Instrument

The pre-test consisted of eight (8) differentiation word problems items (objectives). The eight (8) achievement test items were designed to collect quantitative data. The students were expected to apply the operational definition of PPSA to answer the questions. These questions were based on SHS elective mathematics teaching syllabus objectives (Ministry of Education, 2010) and structured in accordance with the SHS mathematics textbooks. The post-test also consisted of eight (8) items that took parallel content structure as the pre-test. The mathematics curriculum for the SHS was consulted as well as some prescribed mathematics test books for SHS for content validity. The consultation was to gain insight into what students are expected to study under derivative word problems to develop the instrument accordingly. After constructing the tests and the questionnaires, an expert was also consulted to cross-check for face, construct and content validity.

In order to ensure the reliability of the test items and the questionnaires, they were administered on a selected group of forteen (14) students from WASHS/T. They had same characteristics as the selected groups for the study. The reliabilities for the test items and the questionnaires are determined after the pilot study, using Cronbach alpha coefficient. A value equal or greater than 0.7 is an acceptable reliability coefficient, an indication of test items and questionnaires being reliable (Field, 2009).

Data Analysis Procedure

The pretest -post test scores went through descriptive data analysis in an attempt to understand, interpret and describe the abilities of the research participants (Creswell, 2014; Creswell, 2012). Inferential statistics with the Independent-samples $t - test$ at 95% confidence level was used to compare students' achievement in Differentiation Word Problems. This generated information that enables the researcher to evaluate the effectiveness of the intervention. The researcher then compared the performance between the control and the treatment groups in the pre-test, using mean scores (Creswell, 2009). The researcher, again, conducted paired samples t-test for the pretest and post-test results for the control group only and also performed paired samples t-test for the treatment group only.

Results and Discussions

Hypothesis: *There is no statistically significant difference in the mean achievement scores of students taught differentiation word problem using Participatory Problem Solving Approach (PPSA) and those taught using traditional method (TM).*

The researcher determined the effect of PPSA on SHS students' achievement in solving derivative word problems by comparing the scores of both groups in the pre and post tests using independent sample *t*-test and paired samples t-test. The results of the analysis of discriptives statistics are summarized in the tables 1 and 2 below.

Before the intervention, an independent samples t-test was conducted to compare the pre-test mean scores for the two samples to ensure that the samples have the same entry behaviors, baseline, strength and achievement. The pre-test results indicated that mean scores for treatment group ($M = 1.33, SD = .888$) were not significantly higher than mean scores for control group ($M = 1.60, SD = 0.928$).The independent samples t-test also found it not significant as $t(78) = -1.514, p = .427$. The results of the independent samples *t*-test on the participants' scores in the pre-test, are presented in Table 1.

Table 1: Independent Samples *t*-test for Treatment and Control Groups Pre-intervention

Tests	Groups	N	Mean	Standard Deviation	t-value	p-value
Pre-intervention	Treatment Group	40	1.33	0.888	-1.514	0.427
	Control Group	40	1.60	0.928		

Table 1 shows the pre-test mean scores of the treatment and control groups. The results indicate that the mean score for treatment group was 1.33 with a standard deviation of 0.888 and that of the control group was 1.60 with a standard deviation of 0.928. The results indicate that the difference between the achievement mean scores for the treatment and control groups were not significantly (p = 0.427> 0.05). This, therefore, means that the treatment and the control groups were at the same entry behaviors, level, strength and achievement at the start of study.

The same independent samples *t*-test inferential analysis was used to analyze the post-test data collected. The post-test results indicated that the mean scores for treatment group ($M = 5.78, SD = 1.187$) were significantly higher than scores for control group ($M = 3.03, SD = 1.981$) and independent samples t-test found the post-test results of the treatment group to be significant $t(78) = 7.532, p > .000$. The results are presented in Table 2

Table 2: Independent Samples *t*-test for Treatment and Control Groups Post-intervention

Tests	Groups	N	Mean	Standard Deviation	t-value	p-value
Post-intervention	Treatment Group	40	5.78	1.187	7.532	0.000
	Control Group	40	3.03	1.981		

Table 2 shows the post-test achievement mean scores of the treatment and the control groups. The results indicate that the mean score for the treatment group was 5.78 with a standard deviation of 1.187 and the mean score for the control group was 3.03 with a standard deviation of 1.981. The results of the independent samles t-test indicate that the difference between the achievement mean score for treatment and control groups was significant (p = 0.000 < 0.05) which indicate that there has been a remarkable improvement in the achievement of students in the treatment group. The result also affirms that there is significant difference between the mean achievement scores of students taught using PPSA and those taught using TM. Thus, the hypothesis, that there was no significant difference, was rejected. That is Participatory problem solving learning group achieved higher in the post-test scores than the Traditional problem solving group of students.

The results of the post-test pre-test of the treatment only and the control group only were separately analyzed using paired sample t-test. The results indicated that the mean scores for treatment group were significantly higher *(M=5.78, SD=1.187)* than pre-test *(M=1.33, SD= .888),* and paired samples t-test also found this to be significant, *t (39) = 19.663, P < .05*. The means and standard deviation different are *4.450* and *1.431* respectively. The results of the post-test scores in Table 4.5 shows that traditional method of teaching has effected students' achievement more *(M=2.88, SD=2.090)* than the pretest scores *(M=1.80, SD=1.159), t(39)=3.058,p>.004.*

Table 3 shows the paired samples *t*-test for treatment group and control group in the pre-test and post-test.

Table 3: Paired Samples *t*-test for Treatment Group and Control Group

Groups	Tests	N	M	SD	Paired mean difference	t-value	p-value
Treatment Group	Post-intervention	40	5.78	1.187	4.450	19.663	0.000
	Pre-intervention.	40	1.33	0.888			
Control Group	Post-intervention	40	2.88	2.090	1.075	3.085	0.004
	Pre-intervention	40	1.80	1.159			

Table 3 shows the results of the paired samples *t*-test was conducted between the means of both treatment and control groups. The pre-test and the post-test difference were found to be statistically significant in both cases at $p = 0.000 < 0.04 < 0.05$. However, the paired mean difference for the treatment and the control groups were found to be 4.450 and 1.075 respectively. The results from the test show that the paired mean difference of the treatment group is almost four times that of the control group. This difference suggests that the Participatory problem solving approach is more effective than the Traditional method of teaching.

The results from the hypothesis tested indicated that the mean score for the treatment group was 5.78 with a standard deviation of 1.187 and that of control group was 3.03 with a standard deviation of 1.981. The results of the inferential statistics also established that the difference between the achievement mean scores for the treatment and control groups were significant ($p = 0.000 < 0.05$) which indicated that there had been a remarkable improvement in the achievement of students of the treatment group. These findings are consistent with other research works (Perveen, 2010; Mwelese and MWanjala, 2014; Adu, Assuah and Asiedu-Addo, 2015; Ajai, Imoko and O'kwu, 2013; Ali, Hukamdad, Akter and Khan, 2010; Işik, Kaplan, Konyalioğlu, Güler and Kar, 2011). The results, therefore, affirmed that there was significant difference between the mean achievement scores of students taught using PPSA and those taught using Traditional Method. This suggests that the intervention employed had a positive effect on the achievement of students. Since participatory problem solving stresses on student-centered learning in which students work in small groups (Wen-Haw, 2013; Veneranda, 2014) collaboratively, communicatively, and cooperatively. It promotes a high level of interaction among peers and teacher and it also teaches students how to work as a team (Saleh and Abdul Rahaman, 2016)). Working as a team, students identify what they already know, what they require to know and how and where to access new information that may lead to resolution of the problem. This procedure enhances content knowledge while at the same time fosters the development of communication, problem solving, critical thinking, and self-directed learning skills. Participatory problem solving provides students with opportunities to learn and develop the skills and attitudes valued in solving differentiation word problems.

Conclusion

Specifically, the study revealed that students who were exposed to PPSA teaching achievd high as compare to the traditional group in the post-test. This implies that the technique of the teaching strategy (PPSA) used was more effective in solving differntiation word problems than the Traditional Method. Again, the effectiveness of PPSA strategy over the Traditional Method might be attributed to the logical, interactions, discussions, exploration and sequential way in which instructions were presented in PPSA teaching. Students who experienced this type of strategy are more likely to possess a meaningful in-depth knowledge of the content area. Such students will be able to select, organise, recognise snd interpret their thought in an orderly way that is important for mathematical problem solving. These acquisition of skills and knowledgeare needed to improve their competence in solving word problems in derivatives and mathematics in general.

Recommendations

Based on the conclusion of this study, the following recommendations were made:

1. Students should adopt PPSA strategy to learning differentiation word problems.
2. Teachers should adopt PPSA in their teachings of differentiation word problems.
3. Head of second cycle institution should organize PPSA workshops for their teachers so that they apply it in their teaching.

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