Influence of Problem Solving Approach on Secondary School Students' Mathematics Achievement by School Type in Vihiga County, Kenya

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Abstract- In Kenya, the fundamental challenge facing learning of mathematics in secondary schools is how to enhance students' conceptual understanding associated with the learning process. Based on this challenge, the study investigated the influence of using Problem Solving Approach on secondary school students' mathematics achievement by school type. The purpose of this study was to determine whether the use of Problem Solving Approach had any influence on students' mathematics achievement by school type. Students from one hundred and nine schools from Vihiga County formed the population of the study. Stratified random sampling was used to select twelve schools from the 109 schools. The population of the study was 1459 Form Three students selected from the twelve schools that participated in the study. The sample size of 727 students was selected from the 109 schools by the use of purposive and simple random sampling techniques. The Solomon Four-Group design was used in the study. The respondents were assigned in their intact classes to four groups; experimental groups 1 and 3, and control groups 2 and 4. All the groups were taught the same content of the topic Commercial Arithmetic. However, groups 1 and 3 were taught using Problem Solving Approach while groups 2 and 4 were taught by conventional methods. Groups 1 and 2 were pre-tested prior to the implementation of the Problem Solving Approach treatment. Mathematics Achievement Test 1 and Mathematics Achievement Test 2 were used to collect data. The instruments' validity was determined by the researcher, a panel of mathematics educators from the Department of Science and Mathematics Education at Masinde Muliro University of Science and Technology and experienced secondary school mathematics teachers. Reliability coefficients of 0.795 and 0.872 were obtained for Mathematics Achievement Test 1 and Mathematics Achievement Test 2 respectively using Cronbach's Coefficient alpha formula. After the treatment, all the four groups were post-tested. The results showed that increased students' learning occurred among students in the three types of schools and more significantly in the County schools in comparison to the National and Sub-county schools when Problem Solving Approach was used. The study concluded that Problem Solving Approach is a more effective teaching approach to the students in the County schools in comparison to those in the National and Sub-county schools. Therefore, mathematics educators should encourage mathematics teachers to use it and teacher educators to make it part of the teacher-training curriculum.

Index Terms*-* Problem Solving Approach, Secondary School, Mathematics Achievement, School Type.

I. INTRODUCTION

1.1 Background to the Study

Mathematics is one of the core subjects in the Kenya secondary school curriculum. It is an examinable subject for all students (Kenya Institute of Education [KIE], 2006). Much importance is currently attached to it by the society. As a tool, it finds its application in daily lives at home, in the office and in scientific and technological fields. Despite its importance, students have consistently performed poorly in the subject. This is evident from the Kenya Certificate of Secondary Education (KCSE) examination results. The years 2006, 2007, 2008 and 2009 recorded low mean scores of 38.08, 39.46, 42.59 and 42.26 respectively (KNEC, 2010). The mean score figures indicate that there was a slight decline in the overall mean score in the year 2009 compared to the previous year. However, the general performance in the subject is poor as depicted by the low mean scores. This poor performance was attributed to poor teaching and/or learning strategies (KNEC, 2009).

In the recent past, teaching and learning practices have undergone changes of revolutionary proportions; changes underpinned by shifts in psychological and pedagogical theory in teaching and learning process. The new developments advocates for new approaches to mathematics teaching and learning, not only in secondary schools but also in teacher education (Okigbo & Osuafor, 2008). Research findings on learning and memory show that for learning to be effective, the learner should be actively involved in the learning process (Lambros, 2002). Piaget believed that there is no true learning unless the students mentally act on information and in the process, assimilate or accommodate what they encounter in their environment. Unless this assimilation occurs, teachers and students are involved in pseudo-learning, which is knowledge retained only for short time. Efforts made to translate these new conceptions of learning into classroom practices include development of instructional methods that engage the learner actively in the process of knowledge acquisition. Mathematical problem solving is a teaching approach that is learner-centred. It may improve and motivate students' learning, problem solving skills and broad mathematics knowledge, based on deep understanding and problem solving (Major *et al.*, 2000)

Cognitive psychology research has provided considerable insight into the way the learners acquire and organize knowledge. A growing body of research today points to active learning strategies in which the students listen, talk, write, read and reflect as they become directly involved in the instructional process (Roh, 2003). Constructivist theories of learning which had its roots from cognitive psychology place the learner in an active role of knowledge construction. The learner approaches a domain with some prior knowledge about the subject matter constructed from personal experiences, schooling, and social interactions (Okere, 1996). Concepts change as the learner attempts to connect new information with existing conceptual framework. According to constructivist theories of learning, conceptual change in learners should be facilitated by problem solving activities such as having students actively engaged in processing knowledge; confronting their conceptual framework; confronting defending alternatives perspective; linking new concepts to old; and using strategies that encourages both meta-cognition and higher order thinking (Walker & Lofton, 2003).

Effective strategies designed to promote efficient and meaningful learning rely upon connecting prior knowledge to new concepts (Okerere, 2006). The importance of meaningful learning in promoting conceptual understanding that in turn facilitates problem solving was stressed by Bransford and Stein (1984), Eylon and Linn (1988) and Mangle (2008). Research in different areas in mathematics and in other subjects has established the existence of positive relationships between students' meaningful learning approaches and their achievement in mathematics (Wentzel, 2002; Boaler, 2002; Samuelsson, 2008). According to Ramsden (1995) meaningful learners have a deep approach to learning. They tend to build a holistic description of content, reorganise new content by relating it to prior knowledge and/or to personal experiences, are inclined to use evidence, and maintain a critical and a more objective view. Conversely, rote learners have a surface approach to learning; they have a propensity for memorisation of mathematics facts, concepts, principles and strategies and are motivated extrinsically by fear of failure rather than the need to learn and understand.

Students' learning difficulties can often be attributed to ineffective or inappropriate cognitive processes (Herreid, 2003). Earlier, Ramsden (1995) contended that approaches to learning are associated with learning outcomes. According to Novak and Gowin, meaningful learning occurs when individuals choose to relate new knowledge to relevant concepts and propositions they already know (Novak & Gowin, 1984). This calls for commitment on the part of the learner to link new concepts with higher order and more inclusive concepts that are already understood by the learner that can serve to anchor new learning and assimilate new ideas (Novak, 1998).

The persistently low enrollment in mathematics-oriented courses particularly in tertiary institutions have aroused concern of mathematics educators, researchers and policy makers the world over (Changeiywo, 2001; Githua, 2002). As a result most countries are seeking to improve their mathematics education standards by promoting programs that not only enhances effective acquisition of rapidly growing bodies of mathematics knowledge in a well organized framework, but also promotes the learners' capability to learn mathematics meaningfully (Novak, 1998). In practice, while the preponderance of scientific effort swirls around experimental achievements, conceptual achievements continue to be astoundingly important in the overall advancement of mathematics (Wagner & Benavente-McEnery, 2006). If mathematics education aims at preparing students who can think logically and conceptually; solve traditional as well as novel mathematics problems; work efficiently with confidence and accuracy; use meaningful problem solving strategies and are committed to pursuing the study of mathematics; then the focus should be on teaching for understanding rather than students memorising mathematics facts, skills, concepts, principles and strategies (Cooper & Robinson, 2000).

Many students in Kenya perform poorly in mathematics. The poor performance is mainly attributed to poor teaching and learning strategies. It is this poor performance that prompted the Government of Kenya through the Ministry of Education, with assistance of the Government of Japan through Japan International Co-operation Agency (JICA), to initiate a program on Strengthening of Mathematics and Science in Secondary School Education (SMASSE, 2003).

The importance of good teaching cannot be overemphasized. Good teaching encourages high quality learning (Ramsden, 1995). According to Mondoh (2000), students' difficulties in solving problems in mathematics may be traced to: poor understanding of the basic concepts, dependence on algorithms, and inability to apply what they knew, among others. The teaching of mathematics is not just about dispensing rules, definitions and algorithms for students to memorize. There is need to engage students as active participants through discussions and collaboration in problem solving among themselves. If students are given the opportunity to explain or clarify mathematical ideas, more meaningful learning results. Lau (2009) alludes that the mathematics skills required for the youth of today and the adults of tomorrow to function in the workplace are distinct from that for the youth and adults of yesterday. In terms of the 21st century pedagogy, the development of education now requires teaching strategies that emphasize students' involvement (Silva, 2009). Much success lies in students being able to communicate, share and use information to solve mathematical problems. According to Johnson and Johnson (1995), to achieve success in learning mathematics, learners should be given the opportunity to communicate mathematically, reason mathematically, and develop self confidence to solve mathematics problems.

An analysis of the KCSE examination question papers indicates that questions on Commercial Arithmetic keep recurring year after year, yet no marked improvement has been realised in terms of student performance in the topic even as the general performance in mathematics remains poor (KNEC, 2010). This suggests that students have a problem with this topic. The poor performance depicted by students in this topic portrays inadequate understanding of concepts in it. Teachers have been blamed for using inappropriate instructional techniques in teaching this topic. Techniques that promote student-centred learning are seldom used. This is due to poor instructional approaches used in teaching mathematics (Mondoh & Yadav, 1998; Githua, 2001; Changeiywo, 2001; KNEC, 2010). It is however important that students perform well in this topic since Commercial Arithmetic gives useful information applied in daily life at home, in accounts and in commerce (KIE, 2001).

In Kenya, previous studies on performance in mathematics education concentrated on the direct effects of students' background factors and school environment, students' attitudes and type of instruction (Kirembu, 1991; Makau & Coombe, 1994). Mondoh (1995) identified teaching effectiveness, which is influenced by the teaching approach, as the most significant variable in mathematics achievement.

Problem Solving Approach (PSA) has been widely accepted as the way to teach vocational agriculture. On effects of level of PSA to teaching on students' achievement and retention, Boone (1990) found that students' level of achievement and retention was highest when PSA to teach was used. In the same study, Boone found that for high level cognitive items, students taught by PSA exhibited lower achievement loss than those taught by subject matter approach. In an earlier study, Boone (1988) found that high school agriculture students taught using PSA first in an instructional series had higher achievement scores than those taught first using a subject matter approach. Consequently to achieve effective learning and good performance in mathematics, the topic of Commercial Arithmetic need to be taught using student-centred approach. Zechariah (2010) contends that instructional methods employed by the teacher play a significant role in the acquisition of skills and meaningful learning. Instructional methods such as lecture make students become passive and have less interaction with each other in doing tasks. Changeiywo (2001) asserts that the lecture method adopted in schools makes students to be isolated from one another, leading to a high failure rate in sciences and mathematics. Changeiywo is of the view that positive changes take place when a teacher changes the teaching method toward a more student-centred approach. Consequently, an alternative method for the delivery of mathematics knowledge is PSA.

According to Mangle (2008), PSA involves students working in small groups to achieve a common goal, under conditions of positive interdependence, individual accountability, appropriate use of collaborative skills and face-to-face interactions. PSA is the instructional use of small groups through which students work together to maximize their own and each others' learning. Problem solving has its foundation in social-constructivist perspectives of learning. In this approach, the classroom environment is characterized by co-operative tasks and incentives structures and by small group activities. It can be used to teach 'hard' topics in mathematics and also help teachers to accomplish important social learning and human relations goals. Mangle provides benefits on the use of the PSA on students' achievement in mathematics as: students achieve higher grades; develop positive attitude towards mathematics and their social skills are enhanced. PSA also promotes deep learning of materials and help students to achieve better results in mathematics.

PSA has been shown to lead to improved achievement in mathematics to senior students and those in colleges. Samuelsson (2008) found that PSA teaching approach is more effective than the conventional methods in the academic success of students. Segzin (2009) posits that in PSA sessions, students tend to enjoy mathematics, and this enjoyment motivates them to learn. Several researches on PSA have been on senior students and those in colleges in the Western environment. Hence, it was less clear whether PSA could be successfully applied to secondary school students in other countries in which social, religious, educational, and cultural practices are different from those of the Western countries. It is against this background that the current study investigated the influence of PSA on students' mathematics achievement in Commercial Arithmetic in Kenya.

From the foregoing, none of the studies so far sought to find out how PSA influences students' mathematics achievement with an aim of promoting meaningful learning. In an attempt to fill this gap, the current study investigated the influence of PSA on secondary school students' mathematics achievement by school type in Commercial Arithmetic in secondary schools in Vihiga County.

1.2 Purpose of the Study

The purpose of this study was to investigate the influence of Problem Solving Approach (PSA) on secondary school students' mathematics achievement by school type in Commercial Arithmetic.

1.3 Objective of the Study

The specific objective of the study was to determine whether there is any difference in achievement of students taught using Problem Solving Approach (PSA) in National, County and Sub-county schools

1.4 Hypothesis of the Study

The following null hypothesis was tested at an alpha level of 0.05:

HO_1: There is no significant difference between the achievement scores of students taught using PSA in National, County and Sub-county schools.

II. LITERATURE REVIEW

2.1 Problem Solving Approach and Achievement in Mathematics

PSA is a constructivist teaching model based on the assumption that learning is a product of cognitive and social interactions originating in a problem focused environment (Greeno *et al*, 1996). The theoretical philosophy of this approach is derived from John Dewey and discovery learning (Rhem, 1998). Fundamentally, PSA is an educational method in which students develop critical thinking and problem-solving skills in addition to developing an understanding of grasping essential concepts through the analysis of real-life problems (Duch, 1995). Learning takes place throughout a process where learners solve problems in groups. Barrows (1996) labels the main characteristics of PSA as: learning is student-centred and takes shape in small groups of students; teacher act as moderator and facilitator; the problems provide motivation for learning and organizational focus as well as the basis for the advance in problem-solving skills; and self-directed learning aids the acquisition of new information. Besides equipping students with knowledge, PSA could also be employed to improve their problem solving skills, critical and creative thinking abilities, lifelong learning aptitudes, communication skills, group cooperation, adaptation to change and self-evaluation abilities, and enables them to build a far more positive approach to learning (Albanese & Mitchell, 1993).

In PSA, students act as professionals (Gallagher *et al.,* 1999). They are confronted with problems that require clear defining and well structuring, developing hypothesis, assessing, analysis, utilizing data from different sources, revising initial hypothesis as the data collected, developing and justifying solutions based on evidence and reasoning. PSA has been used as an educational tool to enhance learning as a relevant and practical experience, to have students' problem solving skills and to promote students' learning skills. Eng (2001) opined PSA as a philosophy aims to design and deliver a total learning that is holistic to student-centred and student empowerment. Presenting the students with a problem, gives them opportunity to take risks, to adopt new understandings, to apply knowledge to work in context and to enjoy the thrill of being discovers.

Tick (2007) underscores that in the student-centred learning environment that is desirable for PSA, the student is the central figure of the learning-teaching process. The learning objective is not the reproduction, recall and learning of passively received learning material. Rather, it is the active and creative engagement of students in group work and in individual study, thus transferring the skills and knowledge. The individual, autonomous self-directed learning gives the freedom to the learner to decide individually and consciously on the learning strategy and on the time scale to follow. Students have the opportunity to express their ideas and justify their answers verbally. They also have opportunities to engage in cognitively demanding questions (Hiebert & Wearne, 1993).

In PSA, the teacher acts as a facilitator. Roh (2003) argues that within problem solving learning environments, teachers' instructional abilities are more critical than in the traditional teacher-centred classrooms. Beyond presenting knowledge to the students, teachers must engage students in marshalling information and using their knowledge in applied and real settings. In teaching through problem solving, the discussion of a problem and its alternative solution takes longer than the demonstration of a routine classroom activity. Hiebert and Wearne found that classrooms with a primary focus on teaching through problem solving used fewer problems and spend more time on each of them compared to those classrooms without a primary focus on problem solving. Moreover, in problem solving classrooms, teachers ask more conceptually-oriented questions and fewer recall questions than teachers in the conventional classrooms. They also decide the aspects of a task to highlight, how to organize and orchestrate the work of students, what questions to ask to challenge those with varied levels of expertise, and how to support students without taking over the process of thinking for them and thus eliminating the challenge (Stigler & Hierbert, 1999). Thus it is the teacher's role to develop students' reasoning skills. As Weber (2008) avers, "To lead students to develop accurate criteria for what constitutes a good argument, the teacher must have a solid understanding of these criteria" (p. 432).

Learning takes place during the process of problem solving. As students solve problems, they can use any approach they can think of, draw on any piece of knowledge they have learned, and justify their ideas in ways they feel are convincing. The learning environment provides a natural setting for students to present various solutions to their group or class and learn mathematics through social interactions, meaningful negotiations, and reaching shared understanding. Such activities help students clarify their ideas and acquire different perspectives of the concept or idea they are learning (Lester & Charles, 2003).

PSA has important cognitive learning outcomes such as subject achievement, retention, problem-solving skills, learning strategies, approaches to learning (Berkel and Dolmans, 2006; Chin and Chia, 2004). Problem-based tutorial groups positively influence learning. In studies focusing on the cognitive effects of small groups PSA, activation of prior knowledge, recall of information, causal reasoning or theory building, cognitive conflicts leading to conceptual change and collaborative learning construction take place during discussions (Dolmans and Schmidt, 2006). In PSA, students follow a certain pattern of exploration which begins with the consideration of a problem consisting of occurrences that need explanations. During discussion with peers in groups, students try to identify the fundamental principles or processes. Students then stimulate their existing knowledge and find that they need to undertake further study in certain areas. As a result of this, students research the necessary points and then discuss their findings and difficulties within their groups. The discussions held in groups contribute to students' cognitive learning positively (Dolmans *et al.,* 2001).

PSA impacts students' motivation for learning optimistically. A certain cognitive process (i.e. intrinsic interest in subject matter) is facilitated by the process entailed in PSA (Schmidt, 1993). By discussing the subject matter in groups, students become engaged which in turn influences their inherent interest in the subject matter (Dolmans & Schmidt, 2006). Students' intrinsic interest motivates them to develop a full understanding of all the components needed for its solution (Grooves, 2005). Consequently, these cognitive and motivational benefits of PSA have a positive resultant impact on student's academic achievement.

According to Dart *et al.* (2000), PSA produces deep learning which is a modernist method where the leaner actively participates in the learning task so as to reshape the knowledge provided. The surface learning is a product of the conventional method where the learner is completely passive waiting for the teacher to transfer the information directly. Researches have proved that students get influenced by their perceptions of the learning environment when selecting an approach to learning (Mayya *et al.*, 2004). In earlier studies, Raimsden and Entwistle (2010) reported that teaching characteristics such as the methods of learning employed in classes, the teacher's enthusiasm, the level of the knowledge being taught and the pace of progression have a great impact on students' achievement. Margetison (2008) noted that conventional methods of teaching encourage the leaner to adopt the surface learning approach; and that it is PSA method that integrates the four vital elements of the deep learning approach; that is a well-structured knowledge database, active learning, interaction through co-operation and the conditions planned in a way to increase intrinsic motivation.

Mathematical problems are well structured in that they are clearly stated, have known solutions and are evaluated against well known undisputed criteria. Biehler and Snowman (1997) indicate that mathematical problems have given information, obstacles and a goal. According to Polya (1973) the four steps that can help a learner to successfully solve mathematical problems are: identification of the problem, which depends on curiosity and interest of the learner in the subject matter; understanding of the nature of the problem based on specific-domain knowledge and familiarity with problem types; recall of mathematical facts and consultation with other relevant source for the required information in a problem; and formulation and implementation of solution to a problem through; use of algorithms, heuristics, study of worked examples, solution of similar but simpler examples, solving analogous problems, and evaluating the solution by estimating or checking its solution.

In regard to mathematics specifically, a difficulty in some curricular is that algorithms are taught out of context. Lochhead and Zietsman (2001) argue that teaching must be done within the context in order to avoid students' perfunctory performance on algorithms alone. They further assert that much emphasis is on general-purpose strategies that can be applied across a range of mathematical contexts. Beyer (2001) supports Polya's four-step sequence of introducing mathematical problem solving. The teachers reinforce this strategy and elaborate upon it as student progress through the classes, using it as a framework for a variety of solution plans and formulae.

Cook (2001) stresses tasks that engage students in problem-solving and mathematics reasoning. He argues that quality rather than quantity should rule the day in problems that are thought-provoking and those that challenge students' curiosity. Students can also gain from learning strategies such as: trial-and-error, drawing a diagram or model, process of elimination, looking for patterns, simplifying the problem, working backwards, organizing information and then writing an equation. Lochhead and Zietsman (2001) contend that good problem-solvers have these strategies as part of their repertoire. Besides, they have a positive and determined attitude about problem-solving, and awareness in the sense of understanding *how* they solved the problems. This study adapted Polya's problem solving heuristics during mathematics instruction.

Studies involving elementary students showed that students taught through the PSA had higher levels of mathematical understanding and problem solving skills on a computation test than those taught with the conventional methods (Fuson *et al.*, 2000). Other studies involving middle school students (Romberg & Shafer, 2002) revealed that students taught with the Problem Based Instruction had higher levels of mathematical understanding than the students taught by the traditional instruction. Earlier, Wood and Sellers (1997) found that students who received problem-centred mathematics-instruction had significantly higher achievement on standard achievement measures and better conceptual understanding than did those students who had received the traditional instruction. In studies involving pre-service Physics teachers, those taught through problem based learning instruction had higher levels of achievement in comparison to those who received instruction through the traditional methods (Sahin, 2010; Segzin, 2009).

2.2 School Type and Achievement in Mathematics

Vihiga County has national, county, sub-county and private schools. National, county and sub-county schools were used in the study. This is so because students' achievement in mathematics in the three types of schools is not the best. This makes it paramount to seek for a strategy for teaching mathematics that aims at improving its understanding and achievement by students in the three types of schools. Consequently, the researcher's main intention was to investigate the influence of using PSA on student's achievement in the national, county and sub-county schools.

Although the literature reviewed supports the benefits of PSA in mathematics instruction, none of the studies focused on the influence of PSA on students' mathematics achievement in national, county and sub-county schools in Vihiga County. Thus, this study investigated on the influence of PSA on students' achievement in mathematics by school type in Vihiga County secondary schools.

III. RESEARCH METHODOLOGY

3.1 Research Design

The study adopted Solomon's Four Group Design that employed the quasi-experimental procedures. This is because secondary schools classes once constituted exist as intact groups and school authorities do not allow such classes to be broken up and re-constituted for research purposes (Gall, Borg & Gall, 1996). The schools selected were randomly assigned to the treatment and control conditions as intact groups. The pre-test – post-test approach was used to partially eliminate the initial differences between the experimental and control groups (Gibbon & Herman, 1997). The design is shown in Table 1.

Table 1: Solomon's Four Group Design

Groups	Pre-test	Treatment	Post-test
1	O_1	X (Problem Solving Approach)	O_2
2	O_3	C (Conventional Methods)	O_4
3		X (Problem Solving Approach)	O_5
4		C (Conventional methods)	O_6

Source: Adapted from Gibbon and Herman (1997)

In this design, subjects were assigned randomly to four groups. Groups 1 and 3 received the experimental treatment (X) that was the use of the Problem Solving Approach (PSA) in teaching. Group 1 received a pre-test (O_1) and group 2 received a pre-test (O_3). Groups 2 and 4 constituted the control and use of conventional methods in teaching. Finally all the four groups received post-test (O_2, O_4, O_5 & O_6).

3.2 Target Population

The target population of the current study consisted of all Form Three students from public schools in Vihiga County. The county was chosen for this study because there was no study on the influence of the teaching strategy on students' mathematics achievement in terms of school type. Form Three students were chosen because the topic Commercial Arithmetic selected for the study is taught at this level (Kenya Institute of Education [KIE], 2002) and that they could express their mathematical ideas in written form (Githua, 2002). The County has 114 schools: 2 national schools, 10 county schools, 97 sub-county schools and 5 private schools. National, county and sub-county schools were selected. There were 109 such schools with a population of 10,555 students.

3.3 Sampling Procedure and Sample Size

The sampling frame consisted of all national, county and sub-county schools in Vihiga County. The first stage was the purposive selection of Vihiga County and the category of school included in the study sample. Purposive sampling was used to select the two national schools that participated in the study. The remaining schools were stratified into boys' only, girls' only and co-educational schools. Ten schools were then drawn out of the remaining 107 schools. Because of the smaller number of schools to sample from, balloting method was employed. This involved assigning a numeral to each of the 107 schools, placing the numbers in a container and then picking a number at random without replacement. Schools corresponding to the numbers picked and having at least three streams at the Form Three level were included in the study sample.

According to Mugenda and Mugenda (2003), at least 30 students per group are required for experimental research. Twelve schools were sampled. The twelve classes in the twelve schools were assigned to the four groups in the Solomon four-group experimental design. Although it was assumed that the average enrolment was forty students per class, giving the approximate sample size of the study as 1440 students, the actual sample size that participated was 1663 students. During data coding, it was found that some students had either incomplete data and/or missed some test. This reduced the sample size for data analysis to 1459 students. These subjects were used in their twelve intact classes in the twelve schools that were assigned to experimental groups 1 and 3, with 367 and 360 students respectively; and control groups 2 and 4, with 344 and 388 students respectively.

3.4 Research Instruments

Mathematics Achievement Test 1 (MAT 1) and Mathematics Achievement Test 2 (MAT 2) were used to collect data to meet the objective of the study. They were developed and pilot tested prior to the actual conduct of the study. MAT 1 was used as a pre-test and had items on the topic Commercial Arithmetic covered at the Form one level. Its purpose was to establish the entry behaviour of the learners before the treatment. MAT 2 was used as a post-test. It was used to assess Form Three students' achievement in Commercial Arithmetic after the treatment. It was administered after the treatment when all the lessons had been taught. The instruments were pilot tested on 42 Form Three students that did not participate in the study.

3.5 Validity of Instruments

MAT 1 and MAT 2 were assessed for content and face validity. This was done by two experienced secondary school mathematics teachers, the two academic supervisors and two mathematics educators from the Department of Science and Mathematics Education at Masinde Muliro University of Science and Technology. Each panel member assessed the items in MAT 1 and MAT 2 for content coverage and level of difficult. Their responses were measured on a five-point Likert scale. They were scored and transcribed into a percentage score. An average score of above 70% for face and content validity implied that the instrument was appropriate. The averages of the responses of the face and content validity of each of the instruments are as shown in Table 2.

Table 2: Summary of Assessment of Instruments' Validity by Percentage

Instruments	Type of Validity	Mathematics Teachers	Academic Supervisors	Mathematics Educators	Average Percentage	Conclusion
MAT 1	Face	86	74	78	79.33	Appropriate
	Content	88	85	94	89.00	Appropriate
MAT 2	Face	87	82	86	85.00	Appropriate
	Content	90	88	92	90.00	Appropriate

Source: *Researcher's computations from MATs questionnaires*

3.6 Reliability of Instruments

The reliabilities of MAT 1 and MAT 2 were ascertained using test-retest method. The correlation coefficients were ascertained using Cronbach's Coefficient Alpha method (Gall, Borg & Gall, 1996). Correlation coefficients of 0.795 and 0.872 were obtained for MAT 1 and MAT 2 respectively. These values of correlation coefficients were considered appropriate to make possible group predictions that are sufficiently accurate.

3.7 Data Collection Procedures

Before the treatment started, the research assistants from participating schools were inducted for a period of two days by the researcher as pertains to the use of the PSA and conventional methods. They trained the students in the experimental groups pertaining to the requirements and use of PSA for a period of three days. The teachers in the experimental groups were issued with instructional manuals specifically developed for the topic Commercial Arithmetic. After the induction period, the research assistants administered a ninety-minute MAT 1 to students in groups 1 and 2. The MAT 1 scripts were collected and scored for three days in each respective school by the researcher and his assistants. The pre-test scores were used to assess the entry level and homogeneity of the students in the randomly assigned experimental and control groups. The researcher and his assistants taught groups 1 and 3 the topic Commercial Arithmetic using PSA for a treatment period of three weeks. Groups 2 and 4 were taught the same topic using conventional methods where learning was mainly teacher-centred.

Two days after the treatment period, the researcher and his assistants administered a ninety-minute MAT 2 to all the four groups at the same time. The researcher with the help of the research assistants scored and coded the collected data. To ensure uniformity in the marking, the MAT 2 scripts were scored using the belting system as currently advocated by the KNEC.

3.8 Data Analysis Techniques

The data obtained in the study constituted of MAT 1 pre-test scores and MAT 2 post-test scores of the experimental and control groups. The descriptive statistical tests that were done comprised of percentages, means and standard deviations. The inferential statistical tests; the t-test and the Analysis of Variance (ANOVA) were used to analyse data at an alpha level (α) of 0.05. The t-test was used to analyse the pre-test and the post-test influence. It was also used to compare whether students' mean scores were significantly different, based on the pre-test scores of experimental group 1 and control group 2. A comparison of mean scores and tests for significance difference between experimental and control group scores was done using ANOVA. An F-test was used to determine whether the differences were significant.

IV. RESULTS

4.1 Results of Pre-tests

The Solomon Four-Group Design used in this study enabled the researcher to have two groups sit for pre-tests. The aim for pre-testing was to ascertain whether or not the students selected to participate in this study had comparable characteristics before presenting the topic Commercial Arithmetic. To achieve this aim, the students in groups 1 and 2 sat for the pre-test MAT 1. This made it possible for the researcher to: assess whether there was any interaction between the pre-test and the treatment conditions and assess the similarity of the groups before the administration of the treatment (Borg & Gall, 1989).

A total of 711 students were administered with pre-test MAT 1, of which 367 were in group 1 and 344 in group 2. Table 3 shows the t-test of the pre-test scores on the MAT 1.

Table 3: Independent Samples t-test of the Pre-test Scores on MAT 1

Experimental Group 1, N = 367 Control Group 2, N = 344

Variable	Group	Mean	SD	t-value	P-value
MAT 1	1	37.66[a]	8.18	0.313*	0.754
	2	37.88[a]	10.37		

Notes: [a] denotes similar mean scores * Not significant at p<0.05 level
SD: Standard Deviation MAT 1 Maximum Mean Score = 100 df = (1,709)

From Table 3, the experimental group 1 scored a mean of 37.66 and the control group had a mean of 37.88 in MAT 1. From the results, the pre-test mean scores of both groups (1 & 2) obtained were similar on MAT 1. The t-test results analysis reveal that the pre-test mean scores for groups 1 and 2 on MAT 1 measure are not statistically different since the t-value for MAT 1 (0.313), is not significant at 0.05 α-level, df = (1, 709).

An examination of the results in Table 3 indicate that the pre-test mean scores for experimental group 1 and control group 2 on MAT 1 are not statistically different at 0.05 α-level. From the results presented in Tables 3, it suffices that the pre-test MAT 1 mean scores of students in the experimental group 1 and the control group 2 are not statistically different at 0.05 α-level. This indicates that the four groups used in the study were comparable and had similar entry behaviour, hence homogeneous. This made them suitable for the study.

4.2 Influence of PSA on Students' Achievement in Commercial Arithmetic by School type

The post-test MAT 2 scores were analysed to determine the influence of PSA on students' achievement in national schools in comparison to those in county and sub-county schools using one-way ANOVA. This was done in order to test hypothesis one (HO_1) that sought to determine whether there was any difference in achievement of students taught using PSA based on school type . Table 4 shows the post-test MAT 2 mean scores obtained by the students in the three types of schools.

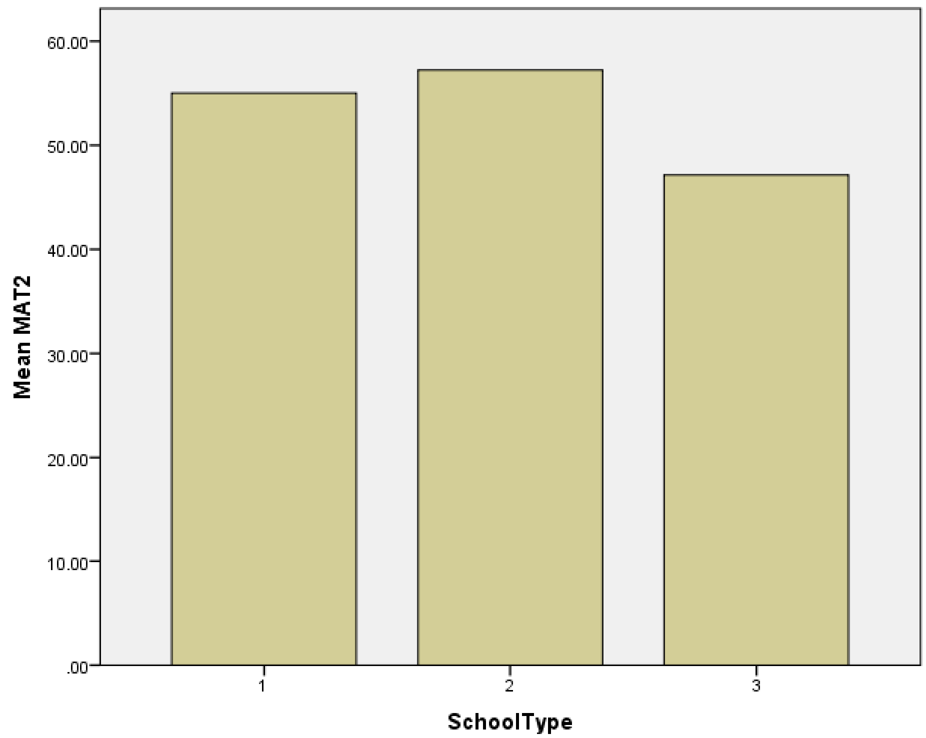
Table 4: MAT 2 Post-test Mean Scores obtained by Students based on School type

School type	N	Mean Score	SD

1 (National)	272	55.04	8.61
2 (County)	223	57.26	7.65
3 (Sub-county)	232	47.12	9.85
Total	**727**	**53.20**	**9.72**

Note: Maximum Mean Score = 100

From Table 4, a total of 727 students in the experimental groups 1 and 3 participated in the study. Of these, 272 students were from national schools, 223 students from the county schools and 232 students from the sub-county schools. An examination of the results show that the highest mean score (57.26) was attained by the students in school type 2 (county schools) followed by (55.04) for the students in school type 1 (national schools) and finally by (47.12) for the students in school type 3 (sub-county schools). The MAT 2 post-test mean score for the students in the county schools is higher than that of their counterparts in the national and the sub-county schools in the two experimental groups 1 and 3. This indicated that the students in the county schools performed better than the students in the national and sub-county schools when taught using PSA. The mean scores are presented graphically in Figure 1.



Notes: 1: National Schools 2: County Schools 3: Sub-county Schools

Figure 1: Post-test means on MAT 2 by School type

In order to determine whether the difference in the MAT 2 post-test mean scores among the three types of schools was significant, a one-way ANOVA was performed. The results of the one-way ANOVA are shown in Table 5.

Table 5: ANOVA of the Post-test Scores on the MAT 2 based on School type

Source of Variation	Sum of Squares	df	Mean Square	F	P-Value
Between Groups	13143.60	2	6571.80	85.76*	0.00
Within Groups	55478.67	724	76.63		
Total	68622.26	726			

* Denotes significant mean difference at the $p<0.05$ level df =(2, 724)

An examination of the results in Table 5 shows that the difference in the post-test MAT 2 mean scores is significant, the F-value (85.76) from ANOVA is significant at $p<0.05$ α-level, df = (2, 724). Having established that there was a significant difference between the MAT 2 post-test mean scores, it was necessary to carry out further tests on the various combinations of the mean scores to find out where the difference occurred.

Table 6 shows the result of the Least Significance Difference (LSD) post hoc comparisons.

Table 6: Post Hoc Comparisons of the Post-test MAT 2 Means based on School type

	(I) Group	(J) Group	Mean Difference (I–J)	P-Value
LSD	1	2	-2.22*	0.005
		3	7.90*	0.000
	2	1	2.22*	0.005
		3	-10.13*	0.000
	3	1	-7.90*	0.000
		2	-10.13*	0.000

Notes: * = The mean difference is significant at the 0.05 level (2-tailed test)
1: National Schools 2: County Schools 3: Sub-county Schools

The LSD post hoc comparisons indicate significant differences ($p<0.05$) between groups 1 and 2, 1 and 3 and 2 and 3. Therefore the differences between the MAT 2 post-test mean scores of the three types of schools are significant at $p<0.05$ α-level (Table 6). Since the MAT 1 pre-test mean scores indicated that there was no significant differences between the entry levels of the groups involved in the study, then it was not necessary to confirm the post-test results by performing Analysis of Covariance (ANCOVA).

The results showed that the mean difference between the school type 1 and 2 (i.e. national & county schools) was significant in favour of the county schools. The mean difference between the school type 1 and 3 (i.e. national & sub-county schools) was significant in favour of the national schools while the mean difference between the school type 2 and 3 (i.e. county & sub-county schools) was significant in favour of the county schools. The net differences in the mean gains between the national and county, the county and sub-county and the national and sub-county schools are 2.22, 10.13 and 7.92 respectively. Overall the results showed that the students in the county schools attained significantly higher achievement in MAT 2 in comparison to those in the national and sub-county schools. This implies that PSA as a teaching strategy had a significantly higher influence on achievement among the students in the county schools. Therefore, the null hypothesis HO_1 indicating that there is no statistically significant difference in the achievement of students taught using PSA in national schools as compared to those in the county and sub-county schools is rejected.

V. DISCUSSION

5.1 Results of the Pre-tests

This study employed the Solomon Four-Group Design. The students were put in four groups such that groups 1 and 3 were the experimental groups while groups 2 and 4 were the control groups. Groups 1 and 2 took the pre-test while groups 3 and 4 did not take the pre-test. Such an arrangement enabled the researcher to determine the presence of any interaction between pre-test and the PSA treatment as well as determine the similarity of the groups before applying the treatment and generalise to the groups which had not received the pre-test (Sharma, 2002).

Sanders and Pinhey (1979) assert that when the two experimental groups (1 & 3) are similar to each other in the post-test as opposed to the two control groups (2 & 4), then the researcher is in a strong position to attribute the differences to the experimental condition. The post-test students' mathematics achievement result in this study did not indicate any interaction between the pre-test and the PSA treatment.

Higher post-test performance by groups 1 and 2 than that of groups 3 and 4 could have been the results if the pre-test provided a practice effect. This is not the case since a comparison of the post-test results of the four groups fails to indicate any practice effect provided by the pre-tests. The results therefore portrayed that the pre-test MAT 1 was suitable for the study.

A comparison of groups 1 and 2 students' pre-test MAT 1 mean scores revealed non-significant differences (Table 3). This results show that the groups were quite similar before the administration of the treatment.

5.2 Influence of Problem Solving Approach on Students' Achievement in Commercial Arithmetic by School type

The results of this study reveal that students who were taught Commercial Arithmetic using PSA in county schools achieved higher mean score in the MAT 2 than those in the national and the sub-county schools (Table 4). This implies that the use of PSA is more effective in improving students' achievement in county schools as compared to those in the national and sub-county schools.

The findings of this study showed that PSA is more beneficial to students in the county schools. This is probably because those students in national schools might be having their own successful strategies, which they may fail to employ when they use PSA and thus get disadvantaged in the process. Studies have shown that using PSA is a difficult process. Students need a lot of training to master its use if they are to derive any benefits from it (Tick, 2007). Thus, it is possible that conformity of students (in county schools) to teachers' demands as well as their consistency in the use of PSA, enabled them master the new techniques as opposed to those in the national schools who are probably predisposed to employ alternative learning strategies. Students in the sub-county schools are in most cases hapless when learning mathematics. This is probably because of poor learning strategies they employ. Thus the use of PSA as a teaching strategy in this study explains the improved achievement among the students in the county schools.

Herreid (2003) notes that students' achievement might be negatively affected by the teachers' approach in presenting the subject matter. Consequently, the teachers' role in the lesson is a major determining factor of the classroom environment. Meaningful learning often develops best in classroom environments that give students more opportunities for more participatory interaction (Cooper & Robinson, 2002; Chin & Chia, 2004). It seems likely that this is the reason why the teacher in the PSA treatment groups provided more student participation opportunities. This is in line with Yuzhi (2003) and Wasike (2003) who found a strong relationship between the nature of the conducive classroom environment and the acquisition of the necessary knowledge, concepts and skills in sciences and mathematics. The PSA resulted in a conducive classroom environment. The teacher was responsible for restructuring and controlling the mathematics' classroom environment in order to allow the students to work interactively in collaborative groups. This led to improved students' achievement in the three categories of schools and especially in the county schools.

The low performance of students in the sub-county schools as compared to those in the national and county schools were unexpected bearing in mind that effective instructional methods that encompasses students' participation in learning are expected to improve on cognitive characteristics of learners compared to the conventional teaching methods (Barchok, 2012). One possible explanation for this perceived contradiction is probably the short period that the intervention took (3 weeks) in the present study. Significant improvement on students' mathematics achievement in the sub-county schools was unlikely to be effected over such a short period of time considering the fact that this is a cognitive characteristic which requires reasonable period of time for the knowledge gained to be discriminated, assimilated and accommodated into the learners' old structures of knowledge before its application. In addition, the achievement measured was directed towards learning in Commercial Arithmetic as a topic and therefore was unlikely to be determined solely by teaching of the one particular topic as was done in the present study.

Though there were positive results from the use of PSA in the sub-county schools, it was apparent that both teachers and students faced some challenges. Ngeow and Kong (2001) alluded that as the PSA requires students to adopt active learning strategies and become more self-directed in their learning, some students faced difficulties in adapting into critical thinkers. According to Wood (2003), the use of the PSA requires a greater number of staff to be involved in teaching and essentially more staff development particularly focusing on facilitation and management of group dynamics (i.e. dependence on other members and inconformity within groups). Goodnough (2003) points out that the use of PSA with large groups is hard due to the difficult in ensuring that groups functioned successfully. Due to time constraints, information is not always properly shared or fully discussed. There can be resentment because some group members take on more responsibility than others. Some students indicate discomfort with the process that there is not enough direction, they request more feedback on the success of their efforts or are uncertain if they have covered all the relevant areas (Boud & Feletti, 1997). However, this study has shown that PSA results in improved students' achievement in mathematics in the three types of schools. In view of this, it suffices to point that the PSA should be adopted for mathematics instruction in Kenyan secondary schools.

The findings of this study have some practical implications to mathematics education. PSA engages students in constructing and altering their own knowledge structures leading to better understanding of mathematics concepts and skills. However, in this study PSA as a teaching strategy was found to be more beneficial to students, particularly in county and national schools by improving on their achievement in mathematics. There is need however to scrutinize the learning strategies of students in sub-county schools in order to identify ways in which the benefits of PSA as a teaching/learning strategy can be harnessed to benefit them too. Consequently there is need for longer training sessions in the use of PSA and direct feedback to give students in the sub-county schools the opportunity to benefit from its use.

The findings of this study also showed that PSA as a teaching strategy has a positive and significant contribution to understanding of mathematics concepts and skills among students in the county and national schools. This is not the case however with the students in the sub-county schools. This implies that in choosing a method of instruction, it is imperative that mathematics teachers consider the uniqueness of each student in terms of academic abilities when handling them. This is particularly necessary to avoid disadvantaging students particularly in the teaching/learning strategies employed in classroom interactions. PSA as a teaching strategy is more beneficial to students in the county and national schools because they are more conforming and consistent in its use within a short time span. Students in the sub-county schools on the other hand might be having other strategies that they consider more successful to themselves. However, the intervention period for this study was notably shorter (three weeks). This factor may probably help explain the low achievement gains among the students in the sub-county schools. A long intervention period might allow ample time for significant gains in the achievement of students in the sub-county schools.

VI. CONCLUSIONS

The following conclusions have been drawn from the analysis of the data presented:

a) PSA has influence on students' mathematics achievement in the national, county and sub-county schools. The PSA positively influenced the students' mathematics achievement in the three types of schools that resulted in their autonomous learning and subsequent ownership of the lessons. Thus, the PSA facilitates students' learning in mathematics.

b) Students in the county schools who are taught using the PSA will learn and achieve significantly better results in mathematics than those in the national and sub-county schools.

VII. RECOMMENDATIONS

On the basis of the findings of this study, the researcher made recommendations that the mathematics educators as well as education stakeholders can employ PSA to enhance effective and efficient mathematics classroom discourse between the teachers and the students. These recommendations are: -

(i) PSA as a teaching strategy has beneficial influence on the achievement of secondary school mathematics students. Secondary school mathematics teachers in Vihiga County should therefore enhance the use of the PSA teaching strategy to address the perennial problem of underachievement, especially among the students.

(ii) PSA has beneficial influence on the understanding among mathematics students in national, county and sub-county schools. Teachers should therefore enhance the use of the PSA teaching strategy to promote meaningful learning among this group of students and especially to those in the sub-county schools.

(iii) The PSA had a positive influence on the students' achievement, especially to those in the county schools, in comparison to those taught by conventional teaching methods. This implies that the problem of low achievement among students in the sub-county schools may be addressed by incorporating the PSA in the teaching at the sub-county secondary school level.

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