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Strategic improvement of mathematical problem-solving performance of secondary school students using procedural and conceptual learning strategies

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The paper examined the possibility of finding out if improvements in students' problem solving perfor-mance in simultaneous linear equation will be recorded with the use of procedural and conceptual learning strategies and in addition to find out which of the strategies will be more effective. The study adopted a pretest, post test control group design. A total of 166 science students drawn from four schools in four local government Areas in Osun state of south-western Nigeria were involved in the study. The students were in Senior Secondary Class Two. These students were assigned to four groups of Conceptual Learning Strategy (CLS), Procedural Learning Strategy (PLS) and Conventional Method (CM) while the fourth group was not taught at all. The first two groups were the experimental groups and the control groups were the last two groups. Treatment was administered for a period of eight weeks. A mathematical achievement test was used as pretest and posttest after validation and was found to have reliability coefficient of 0.76 and item difficulty level ranging between 0.42 and 0.46. Three mathematics teachers who were university graduates were engaged to administer the treatment. The study recorded a significant difference between the problem-solving performance of students in the CLS group and those in the CM group (X_1=30.71, X_2 = 15.66, df =78, t = 16.56, p<0.05).Significant difference in performance was also recorded between PLS group and CM group (X_1 = 24.07, X_2 = 15.66, df =80, t = 10.95, p<0.05). Likewise performance of students in CLS group and those in PLS group differed significantly (X_1=30.71, X_2 = 24.07, df = 84, t = 7.98, p< 0.05). The study therefore concluded that both CLS and PLS were effective in enhancing students problem-solving performance and that conceptual learning strategy was more effective.

Key words: Procedural Learning Strategy,conceptual learning strategy, mathematimatical problem-solving performance.

INTRODUCTION

One of the expected major concerns of a mathematical teacher in the secondary school is the functionality of mathematics taught and the rate and level of achieve-ments by the learners. This is with a view to ensuring that learners can acquire and transfer mathematical know-ledge and applying problem-solving skills in mathematics. In the twenty- first century, developing nations have come to realize the increasing role of science and technology with strong mathematical content in sustainable national development. One way by which this can be realized is to teach mathematical problem-solving skills at the core of science and technological education early enough in the education of the students. And the gains of this exercise begin to manifest in students' good performances in public examination.

It is common knowledge however, that performance of students in mathematics at the secondary school level in Nigeria is not encouraging despite the importance atta-ched to it both as academic discipline and as knowledge that everybody needs in the society as stipulated by the National Policy on Education (FGN) (2004) in Nigeria.

Statistics shown in Table 1 represent a five-yearly rep-ort of the level of performance of secondary school stu-dents in Nigeria in the public examination conducted by the West African Examination Council (WAEC) between 1999 and 2003.

Results presented in Table 1 indicate that a high pro-portion of students record failure grade F9 and low pass grades of P7 and P8. This rate is alarming and equally disturbing. It is most likely that most students have some

Table 1. Results of candidates in mathematics at WAEC May/June School Certificate Examination (1999-2003).

Year/%	Total No	A1-A3	C4-C6	P7-P8	F9	Weak Pass and Failure (P7-F9)
1999%	756680	309074.1	10719114.2	21251428.1	40606853.7	61858281.8
2000%	643604	556838.8	1525624	19608030.9	23028036.3	42636067.2
2001%	1023102	10309410.1	27086126.5	33490732.7	31424030.7	64914763.4
2002%	908235	676987.5	24171126.6	30836934	29045732	59882666
2003%	926212	719557.8	26997329.1	33134835.8	22987824.8	56122660.6

Source: WAEC Statistics Division, Lagos, Nigeria.

mathematical knowledge but they may have almost no understanding of the basic structure of mathematics, thereby making them to resort to memorization of mathematical facts and concepts. One particular area in which students' problems have been documented is algebra. Perhaps, this is so because historically, algebra has represented students' first sustained exposure to the abstraction and symbolism that makes mathematics powerful (Kieran, 1992). The component of algebra that is considered a basic by many mathematics educator (Ballheim,1999; NCTM, 2006) It then becomes the duty of the teacher to teach mathematics in a way to encourage the understanding of the required basic structure of mathematics. One way of achieving this is through a careful and thoughtful selection of appropriate teaching strategy that will help in promoting students' ability to create meaning of mathematical concepts rather than passive reception of ideas.

Procedural and conceptual learning strategies are two of the ways by which learners acquire mathematical knowledge. Hiebert (1986) and Kilpatrick et al. (2001) have earlier identified three strategies leading to procedural knowledge, procedural flexibility and conceptual knowledge. Procedural learning is learning how to do something and therefore yields procedural knowledge. Rittle-Johnson et al. (2001), describes it as learning to execute actions sequences to solve problems, including the ability to adapt known procedures to novel problems. Conceptual learning is learning the basis of something and therefore yields conceptual knowledge which Kilpatrick et al., (2001) describes as an integrated and functional grasp of mathematical ideas. For instance, procedural knowledge enables students to apply the rule of equations to solve simultaneous equations while concepttual knowledge enables students to describe with understanding the rule governing equations and their solutions.

The relationship between learners' knowledge of concepts and their ability to execute procedural skills is an important issue that has been explored in several different fields in cognitive science (Star, 2000). In mathematics too, the relationship between concepts and procedures has been examined but this has been limited to the lower and elementary mathematics (Fussion, 1988; Siegler and Crowley, 1994; Lembke and Reys, 1994; Hiebert and Wearn, 1996; Star, 2000). It is equally important to study the relationship as students continue to learn

mathematics. In developmental psychology, it has been observed that articulating how procedures and concepts interact is critical to an understanding of how development occurs (Rittle-Johnson and Siegler, 1998). The learning of mathematics, which is also psychological, dwells much on both concepts and procedures and there-fore it is necessary to examine how the two contribute to the learning of the subject more so that the order in which students come to have the knowledge of concept and procedures has been reportedly debatable (Star, 2000). For instance, Conceptual knowledge enables learners to recognize, identify, explain, evaluate, judge, create, invent, compare and choose when dealing with mathematical knowledge while procedural knowledge enables learners to apply skills in a routine manner with fluency. There is therefore the need to examine which of the two contribute more to problem-solving skills.

The process of getting mathematical problems solved require proper understanding of the concept underlying the problem as well as the skill of executing and presenting the solution in an acceptable format. The separate contributions of the knowledge of concept and that of procedure in solving mathematical problems are issues of investigation, and hence the need for this study.

STATEMENT OF THE PROBLEM

Problem solving is at the core of learning in mathematics. Personal classroom experiences with secondary school students in Nigeria and results of the private and public examinations show that most learners are yet to acquire the vital problem -solving skills required for success in mathematics and related disciplines. Unless these deficiencies are rectified students will continue to record poor performances in mathematics. This study examines the use of conceptual and procedural learning strategies and tries to provide answers to certain questions with a view to providing means of rectifying the identified deficiencies.

These questions are:

1). To what extent is conceptual learning strategy effective in improving students' problem solving skills?
2). Are problem solving skills of students enhanced by the procedural learning strategy?

Table 2. Mean and standard deviation scores of the four groups in the pretest.

Group	N	$\overline{X}$	S.D
Experimental I	42	7.99	2.01
Experimental II	44	8.24	1.30
Control I	38	8.04	1.62
Control II	42	8.45	1.17

Table 3. ANOVA summary of the differences in the pretest scores of the four groups.

Source	S.S	Df	Ms	F_c	F_t	Remark
Between	5.29	3	1.76			Not significant
Within	1707.54	165	43.08	0.04		
Total	1712.833	168			2.68	

3). which of these two learning strategies will be more effective in enhancing problem solving skills of students?

Research hypotheses

The following hypotheses were generated and tested in this study

1). There is no significant difference in the problem-solving skills of students taught using conceptual-learning strategy and those taught using conventional method.
2). There is no significant difference in the problem-solving skills of students taught using procedural-learning strategy and those taught using conventional method.
3). There is no significant difference in the problem-solving skills of students taught using conceptual-learning strategy and those taught using procedural-learning strategy

PROCEDURE

The study adopted a modified non-equivalent pretest post test control group design where four intact classes were purposively drawn from a population of senior secondary class two (SSII) in Osun State of Nigeria. The modification was the selection of science students into both the experimental and the control groups. These science students were assumed to have similar characteristics in terms of attitude and readiness to the learning of mathematics. Therefore science class selection provided for uniformity of the four groups selected. Three of the groups respectively were taught same aspects of simultaneous equations using conceptual-learning strategy, procedural-learning strategy and conventional method and the fourth group was not taught at all. These four intact classes were drawn from four schools randomly selected from four local government areas randomly selected in Osun State. Altogether, 166 students were involved in the study comprising 42 in group 1, 44 in group 2, 38 in group 3 and 42 group 4.

The instruments used for the study included three instructional packages designed and validated for the teaching of conceptual learning strategy group, procedural learning strategy group and the conventional method group; and an achievement test. This achievement test had reliability coefficient of 0.76 and item difficult level of the items ranged between 0.42 and 0.46. With the aid of the instructional packages students in the three groups were taught the selected content areas for eight weeks employing the services of three trained research assistants. The constructed achievement test was administered to the students before the teaching as pretest and after the eight weeks of teaching as posttest. Separate post-teaching discussions were then held with the three research assistants.

RESULT

Pretest performances of the students in the four groups were compared on their achievement scores in the problem solving skills test using one-way analysis of variance (ANOVA). This was to determine the relative ability of the students before treatment started. Sum-maries of results of the analysis are presented in Tables 2 and 3.

The differences observed in the mean scores of these four groups were subjected to one-way ANOVA and the results in as presented in Table 3.

Result presented in Table 3 showed that there was no significant difference in the performances of the four groups of students before they were exposed to treatment. ($F_{3,165}$ = 0.04 P> 0.05). The students assigned to the four groups were then considered to have uniform level of knowledge of the topics of the study before they were exposed to either the experimental or control treatment.

Performance of the students in the two control groups was also compared using t-test. Result of this comparison is presented in Table 4.

As shown in Table 4, there was a significant difference in the performance of group I and group II (t = 10.23, df = 78, p< 0.05) with students in group I (those taught using conventional method) performing better than those in group II (those not taught as all). In testing the hypotheses generated, control group II was then made use of.

Table 4. T-test summary of the difference in the posttest performance of students in the two control groups.

Group	n	$\overline{X}$	S.d	df	t_c	t_t	Remarks
Group I	38	15.66	3.71	78	10.23	2.04	Significant
Group II	42	8.45	2.38				

p<0.05.

Table 5. T-test summary of the difference in the performance of conceptual learning strategy (DLS) group and conventional method group (CM).

Group	n	X	S.d	df	t_c	t_t	Remarks
CLS	42	30.71	4.47	78	16.56	2.04	Significant
CM	38	15.66	3.71				

p<0.05.

Table 6. T-test summary of the difference in the performance of students in Procedural-Learning Strategy (PLS) Group and C. M Group.

Group	n	$\overline{X}$	S.d	df	t_c	t_t	Remarks
PLS	44	24.07	3.17	80	10.95	2.04	Significant
CM	38	15.66	3.71				

p<0.05.

Table 7. Summary of the difference in performance of students in CLS and DLS

Group	n	X	S.d	df	t_c	t_t	Remarks
CLS	42	30.71	4.42	84	7.98	2.04	Significant
CM	44	24.07	3.17				

p<0.05.

Hypothesis 1. There is no significant difference in the problem -solving skills of students exposed to conceptual learning strategy and those exposed to conventional method.

This hypothesis was generated to find out the effectiveness of the conceptual-learning strategy in improving students problem-solving skills. T-test analysis was employed and the result obtained is presented in Table 5.

Result presented in Table 5 showed a significant difference in the performance of students in the CLS group and CM group with students in CLS group recording significant improvement in problem-solving skills over those in the CM group (t = 16.56, df = 78 p< 0.05). Hence the null hypothesis was rejected.

Hypothesis 2. There is no significant difference in the problem -solving skills of students taught using procedural learning strategy and those taught using conventional method.

This hypothesis was aimed at finding out if procedural method was effective over the conventional method in im-

proving students problem-solving skills. Scores of students obtained in the two groups were subjected to t-test analysis and the result obtained is presented in Table 6.

Result presented in Table 6 showed a significant difference in the improvement of problem-solving skills of students exposed to procedural-learning strategy and those exposed to conventional with those exposed to PLS scoring higher than those in CM group (t= 10.95, df = 80, P< 0.05). Thus the null hypothesis raised was rejected.

Hypothesis 3: There is no significant difference in the problem-solving skills of students exposed to CLS and those exposed to PLS. This hypothesis was raised to compare the relative effectiveness of DLS and PLS. Data gathered in the two groups were subjected to t-test analysis and the result obtained is presented in Table 7.

Result contained in Table 7 showed a significant difference in the performances of students exposed to CLS and those exposed to PLS. Those in the CLS group performed better in problem solving exercises in mathematics than those exposed to PLS (t = 7.98, df = 84, P< 0.05). Hence the null hypothesis raised was rejected.

DISCUSSION

The findings of this study have shown that both DLS and PLS were effective in enhancing students' problem-solving skills when compared their use with that of conventional method of teaching solutions of simultaneous equations. The study further showed that DLS was more effective than PLS. This finding may be attributed to the features of conceptual learning strategy, which emphasizes conceptual understanding of solutions of simultaneous equations rather than rote learning or surface ideas about simultaneous equations and their solutions. In the study conducted by Cardinate and Smith (1994) on learning strategies training to achieve learning objectives, it was reported that the scores of the group who received strategy training were significantly higher than those of the control group. Tennyson (1983) had also earlier reported that learning strategies embedded in instructional content improve learning and cognition. That students exposed to CLS performed better than those exposed to PLS was likely to be as a result of the features of conceptual knowledge acquisition which include the fact, that the end point of its acquisition is when factual or principal knowledge can be used to recognize, identify, explain evaluate, judge, create, invent, compare and choose. Although, research such as that of Branford, Brown and Cocking (1999), has indicated that both conceptual understanding and procedural understanding are important components of proficiency in solving mathematical problems, it is however added that students who memorize procedures alone may not be sure of when to use what they know. The phases of conceptual learning, which include construction of meaning of the concepts being handled, organization of knowledge of the concept and strategic storage of the knowledge goes beyond facts memorization, and this puts conceptual knowledge at an advantage over procedural knowledge.

Conclusion

The use of conceptual learning strategy as a method of teaching solutions to simultaneous equations has been found to be effective in improving students' problem-solving skills over the use of either procedural-learning strategy or the conventional method. The use of CLS enables students to solve both routine and non-routine problems in simultaneous linear equations rather than being able to only execute algorithm in routine problems. In an attempt to assist students to recognize that mathematics is about relationship and not a body of rules to be remembered by heart, the use of CLS is recommended. This, in addition to improving students' skills of solving problem, would also improve attitude to, and way of looking at the subject.

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