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Effectiveness of First Principles of Instruction in Promoting high Achievement of students in Mathematics: Implications for physics teaching

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Abstract
The study focused on the effectiveness of First Principles of Instruction in promoting students' achievement in mathematics especially in Number and Numeration. The study employed a non-equivalent control group quasi-experimental research design using a sample of 400 students. The instrument for data collection was Number and Numeration Achievement Test [NNAT] which was properly validated. The internal consistency reliability of the multiple-choicetest was 0.97, using Kuder-Richardson 20 (KR-20), while the inter-rater reliability of the essay test was 0.94, using Kendal coefficient of concordance. Mean was used to answer research questions, while the hypotheses were tested at 0.05 level of significance, using the analysis of Covariance (ANCOVA). The result of the study showed that First Principles of Instruction improves the mean achievement scores of students in Number and Numeration more than the traditional lecture method. There was no statistically significant different in the mean achievement scores of male and female students in Number and Numeration after being exposed to First Principle of Instruction, an indication that there is no gender bias in using this method. It was recommended that First Principle of Instruction should be used by mathematics teachersto improve students' achievement in mathematics and mathematics related subjects like physics.

Keywords: First Principles of Instruction, Mathematics, Number and Numeration, Achievement, Physi teaching

Introduction

Despite the acknowledged contribution of mathematics to nation building, poor achievements of students in it keep nagging at the conscience of every nation. For instance, West African Examination Council (WAEC) (2014, 2015, 2016, 2017, and 2018) reported that students' achievement in mathematics show a progressive decline in quality and number of passes in Senior School Certificate Examinations (SSCE). National Examination Council (NECO) (2013, 2014, 2015, 2016, and 2017) gave similar reports of poor achievements of students in mathematics in both the Basic Education Certificate Examination (BECE) and Senior School Certificate Examination (SSCE), especially in Number and Numeration. In a recent study, it was noted that the performance of students in mathematics external examinations in Nigeria has been poor (Onah et al., 2020). In addition to that, Ugwuanyi et al. (2020) revealed that there a higher percentage of undergraduate students perform relatively poorly in mathematics. Students' poor performance in mathematics examinations in Nigeria has constituted a serious worryto both mathematics educators and parents (Ugwuanyi, Okeke & Asomugha, 2020).Onah et al. also opined that the rate of students' poor performances in mathematics is becoming a disturbance to educators of Mathematics and such calls for immediate attention. Ugwuanyi et al. (2020) opined that the courses of students' poor performance in mathematics could be attributed to the way the concepts are being presented by the teachers.

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Number and Numeration is the first theme in mathematics curriculum from pre-nursery through secondary school. Number refers to an idea or concept of quantity (Channon, Macrae &Chima, 2018). For instance, the number two (2) represents the concept of quantities that are two. Example, two bottles, two goats, two boys. But different cultures have different ways of representing two. Our forefathers used strokes // to represent two. Some even used objects but the Arabs represent two with symbol ii. Hence, we talk of Arabic numerals. On the other hand, Numeration is the symbolic representation of numbers. It is a process of counting (naming numbers) or writing numbers or the method of calculating (example, addition, subtraction, multiplication and division). The knowledge acquired from Number and Numeration helps to enumerate, calculate, collate, analyze and relate as well as for developing scientific structures and drawing conclusions. However, inspite of the usefulness of Number and Numeration, students' achievement in this area is poor. Some reasons which have been adduced by researchers to explain students' poor achievements in mathematics specifically in Number and Numeration include, students lack of interest (Obi, 2014), lack of retentive memory (Agashi, 2014), inappropriate instructional strategies (Nzewi, 2003; Ali, 2008; Nwaodo 2016) as well as teacher-centered or traditional lecture method (Agashi, 2014) which is a variable of interest in this study. As a result of poor achievement of students in both the junior and senior secondary school levels, the crucial task in the field of mathematics education is the improvement in the teaching and learning process (Singh, 2010). Much of the research on effective mathematics teaching and learning should focus on instruction that promotes students' involvement and activity. The instructional style should move away from traditional lecture method of instruction which is teacher dominated and move towards monitoring students' readiness and checking for their understanding. This strategy, which First Principles of Instructions seems to provide, can be done through encouraging the learners in solving relevant real-world problems or tasks that are personally meaningful to them.

A first principle is the first basis from which a thing is known. It cannot be deduced from any other parameter or assumption. In philosophy, a first principle is a basic, foundational proposition or assumption. In Physics, calculation is said to be from first principles if it starts directly at the level of established laws of physics and does not make assumptions. In mathematics, first principles referred to as axioms or postulates. A classic example is that of Euclidean geometry in which its hundreds of propositions can be deduced from a set of definitions, postulates and common notions; all of which constitute first principles. First Principles of Instruction was propounded by Merrill (2002) after reviewing, synthesizing, harmonizing and integrating many models of teaching into five inter-related principles. The process begins with activation and continues through demonstration, application and integration, all based on real world problem, according to Merrill (2002) as shown below

1. Task/Problem-centred (let me do the whole task): Students learn more when instruction is centred on relevant real world problem including series of task/problem that progress from simple to complex.
2. Activation (where do I start?): Students learn more when they are directed to recall prior knowledge, to recall a structure for organizing that knowledge or are given structure for organizing a new knowledge.
3. Demonstration (Don't just tell me, show me): Students learn more when new knowledge is demonstrated to them in the context of real-world task or problem
4. Application (Let me do it): Students learn more when they perform real-world tasks or solve real-world problems and receive feedback and appropriate guidance during that application.
5. Integration (watch me do it): Students learn more when they are encouraged to integrate their new knowledge into their life through reflection, discussion, debate and or presentation of new knowledge.

First Principles of Instruction therefore are instruction that must follow from the original name of a concept which is the fundamental approach to instruction that must be taught through the Merrill's (2002) four-phase cycle of instruction that activates prior knowledge, demonstrates new knowledge, has the students apply new knowledge and integrates new knowledge into the learner's life meaningful learning to occur.

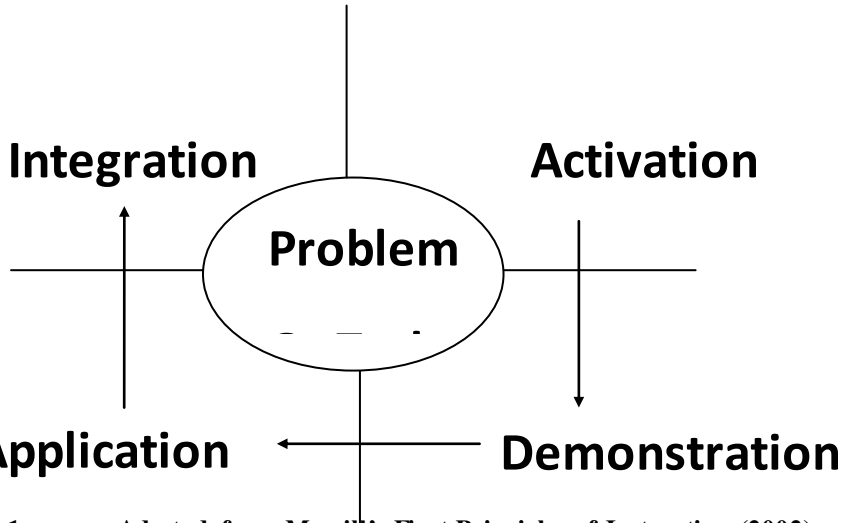
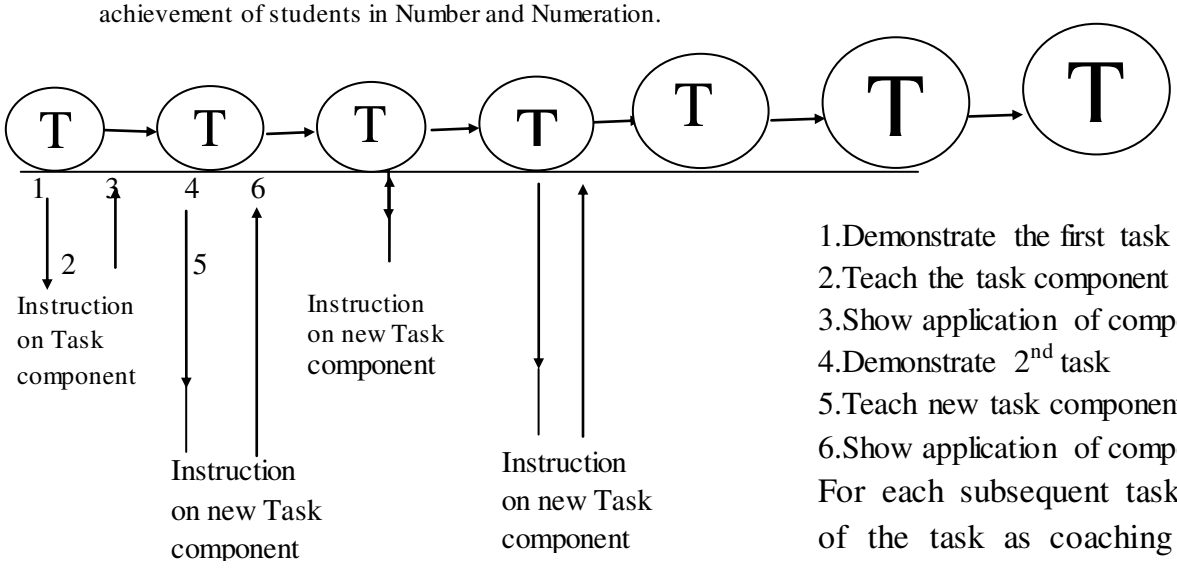


Figure 1: Adapted from Merrill's First Principles of Instruction (2002)

This figure illustrates the instructional phases that involves the students in four distinct phases of instruction viz: activation of prior experience, demonstration of skills, application of skills and integration of these skills into real-world activities. Much of our instructional practice including traditional lecture method concentrates primarily on phase 2 and ignores the other phases in this cycle of learning. Thus, inability to implement one or more of these principles could undermine effective learning and may lead to poor achievement of students in Number and Numeration.



1.Demonstrate the first task
2.Teach the task component skills
3.Show application of components to task
4.Demonstrate 2nd task
5.Teach new task components
6.Show application of components to task.

For each subsequent task, learners do more of the task as coaching is decreased until learners can do subsequent tasks on their own.

Figure 2: Coaching Procedure and Progression of tasks in Merrill's First Principles of Instruction (2002).

The figure above illustrates the instructional sequence in First Principles of Instruction. As shown in figure 2, the Ts in the figure indicate a progression of whole complex tasks from the same class of tasks. The increase in the size of Ts indicates an increase in task complexity with each subsequent task in the progression. Here the first task is demonstrated to the students. Secondly, learners are given instruction- presentation, demonstration, application of the skills required to do this task. This instruction does not teach all there is to know about the given topic or component skill but only what the learners need to know to complete the task. Thirdly, the whole task is revisited at this point and the learners are shown how these component skills were applied to complete the task or solve the problem. This constitutes one cycle of instruction. Fourthly, a new, slightly more complex task is then given to the learners. Learners are asked to apply their newly acquired skills to this task. In addition, learners are taught additional skills or more detail for the initial skills that are required

for this new task. Again, learners are shown or asked to recognize how the previous and new skills are used to complete the task. This constitutes a second cycle of instruction.

This cyclical procedure is repeated for each new task in the progression, with the learners required to do more of the task as they acquire skill, while the instructional system demonstrates less and less. Eventually learners are expected to complete the next task in the progression on their own. If the progression of the task is carefully chosen and sequenced, then when learners have demonstrated their ability to satisfactorily complete one or more whole tasks without coaching or additional demonstration, they have acquired the skill intended by the goals of the instruction. This strategy involves a progression of increasingly complex tasks and a corresponding decreasing amount of learner guidance and coaching.

Teachers using these four cycles of instruction especially in Number and Numeration can achieve the following results. Student-centered teaching, less lecturing and acquisition of integrated set of skills by students based on the integrated nature of the study. Through these activities the students learn the concept much better as they tried to figure it out themselves. This is because, it makes students to be actively involved in the teaching and learning process. It also strengthens Bruner's theory of instruction which encourages both genders, male and female students to construct knowledge based on prior experience, an attribute that enhances students' achievement. This has necessitated the need to explore the influence of gender in this study.

Gender is the observable disparity between males and females in terms of position, power or academic achievement. Differential achievement of students by gender has become an age-long research in education. Gender issues in education have become so popular that it would appear as if there is a raging competition between males and females with no consensus among researchers on gender achievement in science and mathematics. While research reports by Usman and Musa (2015); AjaiandImoko, (2015) have shown that male students performed better than their female counterparts in mathematics and science, those of Kurumeh (2004); Rabah, Velooand Perumal, (2014) are in sharp contrast, meaning that females are superior to males in mathematics achievement. Some other researchers found that both genders achieve equally (Obi, 2014; Agashi, 2014). Since current literature has not settled the issue of gender in academic achievement, it was explored in this study.

Achievement in this context means the cognitive achievement of male and female students in terms of passes in mathematics tests administered in private or public examinations. Students' achievements according to WAEC (2017); NECO (2018) have continued to decline, despite the use of various models as shown in literature to promote achievement. A change in instructional method, like First Principles of Instruction was therefore, explored. Evidence has shown that First Principles of Instruction which has become a viable teaching and learning process is an effective way to promote students' participation, enthusiasm and focuses on problem solving skills for learners to accomplish learning tasks in the classroom (Nelson, 2008; Gardner, 2011). Some researchers have evaluated the effectiveness of First Principles of Instruction in different subject areas. These were in the areas of Computer studies (Thomson, 2002), Physics (Mayer, 2004) and Introductory Biology (Gardner, 2011). However, despite significant results recorded in other subjects, evidence available to the researchers shows that not much has been done in the use of First Principles of Instruction as a teaching and learning strategy in mathematics and specifically, in Number and Numeration. This was what this study investigated.

Problem of the Study

The chief examiner's reports on West African Senior School Certificate Examination (WASSCE) and National Examination Council (NECO) on Basic Education Certificate Examination (BECE) for five years indicated that a good number of students failed questions from Number and Numeration especially, in concepts like Least Common Multiples of Number, Highest Common Factors and Fractions. However, the report did not indicate whether or not both genders achieved equally. According to research studies, this low level of students' achievement has been attributed to poor teaching methods and strategies especially such method like traditional lecture method which does not make for students' involvement and activity in the learning process. For instance, in the topic of least common multiples, teachers still use the product of prime factors method which is a teacher dominated instructional process as against the First Principle of Instruction method which elicits the meaning of multiples, common multiples and factors. The fundamentals of these concepts are lost when traditional lecture method which negates the need for active learning is used leading to poor achievement according to WAEC and NECO reports.

Although WAEC and NECO reports did not differentiate poor achievement of students with respect to gender, achievement by gender has received increasing attention as it has produced varied results, painting an inconsistent picture of achievement for the two genders, males and females Thus, it seems pertinent to study gender differences in mathematics achievement, specifically, in Number and Numeration, which has continued to widen over the years in favour of the males. Literature reviewed indicated that gender gap can be narrowed if both genders are exposed to the amount and type of experiences especially through constructivists' models of

teaching, like First Principles of Instruction. Hence, the problem of this study was to investigate the efficacy of First Principles of Instruction in promoting mathematics achievement among junior secondary school students.

Purpose of the Study

The general purpose of this study was to determine the efficacy of First Principles of instruction on students' achievement in Number and Numeration. Specifically, this study sought to find the;

1. Mean achievement scores of students in Number and Numeration when exposed to First Principles of Instruction and traditional (talk chalk) lecture method of teaching
2. Mean achievement scores of male and female students in Number and Numeration when exposed to First Principles of Instruction.

Research Questions

The study was guided by the following research questions.

1. What are the mean achievement scores of students in Number and Numeration when taught with First Principles of instruction and those taught with traditional method?
2. What are the mean achievement scores of male and female students in Number and Numeration when taught with First Principles of Instruction?

Hypotheses

The following null hypotheses were formulated to guide the study and were tested at 0.05 level of significance.

Ho_1: There is no significant difference in the mean achievement scores of students in Number and Numeration when taught with First Principles of Instruction and traditional lecture method.

Ho_2: There is no significant difference in the mean achievement scores of male and female students in Number and Numeration taught using First Principles of Instruction.

Materials and Method

The study employed a quasi-experimental research design involving non-equivalent control group design. The design was considered appropriate because intact classes were used as a group in each school and therefore selection of each student was not by randomization. Similarly, Ejimonye et al. (2020a,b) and Onah et al. (2020) have adopted the design in their recent studies. The study was conducted in Nsukka education zone of Enugu state, Nigeria, made up of three local government areas with 58 secondary schools. The population of the study was 4,489 junior secondary school one students. The sample of the study was 400 students, made up of 188 males and 212 females from six secondary schools, purposively sampled, based on specific elements that would satisfy some predetermined criteria. The instrument for data collection was Number and Numeration Achievement Test (NNAT), made up of 8 essay and 30-multiple choice questions developed by the researchers using Test Blue Print to ensure content validity. The instrument was validated by three experts from the Department of Science Education, University of Nigeria, Nsukka. The instrument was trial-tested on 30 students from a co-educational school in another education zone of the state. The test-retest stability measure of the essay and multiple-choice tests were 0.99 and 0.79 respectively, using pearson r, while the internal consistency of the multiple choice test was 0.97, using Kuder-Richardson 20 (KR-20) formula. The inter-rater reliability of the essay test was 0.94, using Kendal coefficient of concordance. Six research assistants were trained on the conduct of this study, using manual on Merrill's First Principles of Instruction. Students in both experimental and control group were pretested before the commencement of the study. After collating pretest scores by the research assistants, the actual study commenced on the two groups based on the subject matter. The data obtained from the study were analyzed using mean and standard deviation to answer research questions. Hypotheses were tested at 0.05 level of significance using the analysis of Covariance (ANCOVA)

Results

The results are presented in tables according to the research questions and hypotheses that guided the study.

Research Question 1: What are the mean achievement scores of students in Number and Numeration when taught with first principles of instruction and when taught with the traditional method?

Table 1: **Meananalysis of the achievement scores of students in Number and Numeration when taught with First Principles of Instruction (FPI) and Traditional Method (TM)**

		Pretest		Posttest		
Instructional Methods	**n**	$\bar{x}$	**SD**	$\bar{x}$	**SD**	**Mean gain**
FPI	208	40.04	7.39	61.97	6.02	21.93
TM	192	39.18	6.87	50.35	8.08	11.17

The result above shows that the pretest mean achievement scores of students in Number and Numeration when taught with first principles of instruction (FPI) was 40.04, with a standard deviation of 7.39 while the posttest mean was 61.97 with a standard deviation of 6.02. The difference between the pretest and posttest means was 21.93. On the other hand, when taught with traditional method (TM) the students had a pretest mean of 39.18 with a standard deviation of 6.87 and a posttest mean of 50.35 with a standard deviation of 8.08. The difference between the pretest and posttest means was 11.17. This means that pretest results showed almost equal performance among the students. For both FPI and TM, the posttest means were greater than the pretest means, with students taught using first principles of instruction (FPI) having a higher mean gain than their counterparts who were taught using the TM. This implies that the First Principles of Instruction (FPI) seems to improve the mean achievement scores of students in Number and Numeration than the traditional lecture method (TM).

Ho_1: There is no significant difference in the mean achievement scores of students in Number and Numeration when taught with First principles of instruction and traditional method.

Table 2: Analysis of Covariance (ANCOVA) of difference in the mean achievement scores of students in Number and Numeration when taught with First Principles of Instruction (FPI) and Traditional Method (TM)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	20888.103	4	5222.026	164.630	.000
Intercept	12758.892	1	12758.892	402.239	.000
PretestAchi	7128.291	1	7128.291	224.728	.000
Methods	11952.603	1	11952.603	376.820	.000
Gender	233.700	1	233.700	7.368	.072
Methods * Gender	70.101	1	70.101	2.210	.138
Error	12529.274	395	31.720		
Total	1305463.000	400			
Corrected Total	33417.377	399			

a. R Squared = .625 (Adjusted R Squared = .621)

The result in Table 1shows that an F-ratio of 376.820 with associated probability value of 0.000 was obtained. Since the associated probability (0.000) was less than 0.05 set as the benchmark for taking a decision, the null hypothesis of no significant difference in the mean achievement scores of students in Number and Numeration when taught with First principles of instruction (FPI) and traditional method (TM)wasrejected. Therefore, inference drawn was that there was a significant difference in the mean achievement scores of students in Number and Numeration when taught with First principles of instruction (FPI) and traditional method (TM) in favour of the experimental group.

Research Question 2: What are the mean achievement scores of male and female students in Number and Numeration when taught with the First Principles of Instruction?

Table 3: Means and Standard Deviations of Pretest and Posttest Mean Achievement Scores of Male and Female Students in Number and Numeration in the Experimental Group

			Pretest		Posttest		
Group	Gender	**n**	$\bar{x}$	**SD**	$\bar{x}$	**SD**	**Mean gain**
Experimental (FPI)	Male	90	41.83	6.55	62.64	6.23	20.81
	Female	118	38.67	7.73	61.45	5.83	22.78

The result above shows that the male students had a pretest achievement mean score of 41.83 with a standard deviation of 6.55 and a posttest mean score of 62.64 with a standard deviation of 6.23. The difference between the pretest and posttest means was 20.81. On the other hand, the female students had a pretest achievement mean score of 38.67 with a standard deviation of 7.73 and a posttest mean score of 61.45 with a standard

deviation of 5.83. The difference between the pretest and posttest means for the female group was 22.78. For both male and female groups, the posttest means were greater than the pretest means with female students having a slightly higher mean gain in Number and Numerationthan their male counterparts.

Ho_2: There is no significant difference in the mean achievement scores of male and female students in Number and Numeration taught with First Principles of Instruction.

Table 4: Analysis of Covariance (ANCOVA) of the difference in the mean achievement scores of male and female students in Number and Numeration in the experimental group

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2892.765[a]	2	1446.382	64.430	.000
Intercept	11110.436	1	11110.436	494.924	.000
PretestAchi	2819.817	1	2819.817	125.611	.000
Gender	8.647	1	8.647	.385	.536
Error	4602.000	205	22.449		
Total	806179.000	208			
Corrected Total	7494.764	207			

a. R Squared = .386 (Adjusted R Squared = .380)

The result as presented in Table 4 also shows that an F-ratio of 0.385 with associated probability value of 0.536 was obtained. Since the associated probability (0.536) was greater than 0.05 set as the benchmark for taking a decision, the null hypothesis of no significant difference in the mean achievement scores of male and female students in Number and Numerationwasnot rejected. Thus, inference drawn was that there was no significant difference in the mean achievement scores of male and female students in Number and Numeration.

Discussion of the Findings

The findings of this study were discussed under the following subheadings.

- Students' Achievement in Number and Numeration when exposed to First Principles of Instruction and traditional method
- Influence of Gender on Students' Achievement in Number and Numeration when taught with First Principle Instruction.

Students' Achievement in Number and Numeration

The mean achievement scores of the two groups; that is, students in the experimental group and those in the control group were displayed in Table 1. Both groups were pretested to determine their initial knowledge and interest before the commencement of the experiment and the result showed no significant difference between them. But upon application of First Principles of Instruction on the experimental group, the result indicated that students in First Principles of Instruction group had a mean achievement score of 61.97 as against 50.35 by students in the control group. This result showed that students in the experimental group performed better than their counterparts in the control group. This result was further confirmed by the result in Table 2, which revealed that First Principles of Instruction was a significant factor on students' achievement in Number and Numeration at $P<0.05$ level of significance.

The positive and higher achievement might have been as a result of the method which allows students active involvement in the learning process that takes them through the four-phase cycle of instruction that activates prior experience, demonstrates new knowledge to the students, has the students apply their new knowledge and encourages them to integrate that knowledge into their lives for meaningful learning to occur.

The effectiveness of First Principles of Instruction over the traditional method as discovered might not be unconnected with the First Principles of Instruction class scene in which students seemed to be more actively involved in identifying key principles for themselves than the control group. This study agrees with Thompson (2002), Mayer (2004) and Gardner (2011) that First principles of Instruction is an effective method when compared with the traditional method.

Influence of Gender on Students' Achievement in Number and Numeration when exposed to First Principles of Instruction

The result in Table 3 revealed that male students had a mean score of 62.64 while female students had a mean score of 61.45 in the experimental Post-Number and Numeration Achievement Test (POST-NNAT). There appears to be a difference in achievement between male and female students. However, this mean difference was not statistically significant as shown in Table 4 at $P<0.05$ level of significance. In other words, gender does not have a significant influence on students' achievement in Number and Numeration, an indication that there is no gender bias in using this instructional strategy. This may be because improved instructional strategy can close the gender gap in achievement in mathematics that has been reported in many studies over the years in favour of the male students. Hence, the result of no significance difference may be attributed to the effect of First Principles of Instruction which is rooted in the constructivist Principles of teaching and learning.

This finding agrees with Agashi (2014), who found that using Advanced Organizer Model (AOM) as an instructional strategy in mathematics promoted equal achievement between male and female students. It also buttresses Obi's (2014) finding that Origami as an instructional strategy and instructional material bridges the gap between male and female students in terms of achievement.

Conclusion

Based on the results obtained, the following conclusion can be deduced.

1. The use of first Principles of Instruction as instructional approach significantly enhanced students' achievement in Number and Numeration when compared to traditional method. The study has therefore lent support to the growing pool of evidence from studies that instructional strategies are among the key variables that can improve achievement of students in mathematics. Hence, being able to figure it out themselves promoted achievement among the students in the experimental group.
2. This study has further lent support to some other research findings on gender to the effect that type of instructional techniques can close gender gap in mathematics achievement as has been established with the use of First Principles of Instruction. In other words, First Principles of Instruction provided equal achievement for male and female students in the experimental group.

Educational Implications of the Study

The following are the implications of the study based on the findings.

1. The finding that First Principles of Instruction was more effective when compared with the traditional method of instruction is an indication that medium of instruction plays a major role in students' achievement in Number and Numeration. In other words, the problem of poor achievement of students in Number and Numeration can be ameliorated by the use of First Principles of Instruction instead of traditional method.
2. The finding that there was no significant difference in the mean achievement scores of male and female students show that First Principles of Instruction can create uniform learning conditions for all students irrespective of gender.

Recommendations

Based on the findings of this study, the following recommendations are made.

1. Mathematics teachers should endeavour to use First Principles of Instruction because this strategy has been found to be very effective in achievement compared to traditional method.
2. Government should organize frequent workshops and seminars for primary school teachers and secondary school mathematics teachers through the ministry of education on how to employ this method in teaching and learning since it has been found to be efficacious in classroom instructions.

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