International Journal of Applied Mathematics
& Statistical Sciences (IJAMSS)
ISSN(P): 2319-3972; ISSN(E): 2319-3980
Vol. 5, Issue 3, Apr - May 2016; 83-94

International Academy of Science,
Engineering and Technology
Connecting Researchers; Nurturing Innovations

ESTIMATION OF ERRORS COMMITTED BY FURTHER MATHEMATICS STUDENTS IN LOGICAL REASONING AND REMEDIATION USING WILSON'S LEARNING CYCLE

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ABSTRACT

Errors committed by further mathematics students in logical reasoning are estimated and remediation offered, using Wilson's learning cycle. Three research questions were answered and one hypothesis was tested at 0.05 level of significance. Informal experimental design, specifically, before-and–after without control design was adopted for the study. Sixty (65) SSII students (44 males, 21 females) from four co-educational public secondary schools in Northern Education Zone of Plateau State were used for the study. Purposive sampling technique was used to select schools that met the criteria of the study. Further mathematics teachers of the schools received training from the researchers for one week, after which they taught their students. All the students completed the same unit covered within a period of five weeks. The instrument used for this study was Error Remediation Items (ERI) with rubrics as Marking Guide. The rubric was developed based on seven (7) different types of errors including symbolic, comprehension, transformation, process skill, encoding, careless and logical errors. The reliability coefficient of the instruments was 0.86, determined using Kendall's coefficient of concordance. The Error Remediation Items were administered as both pretest and posttest. Frequency count and Percentages was used to answer question 1, Wilcoxon Signed Rank Test to answer question 2 and Mann-Whitney U Test to answer question 3, and test the hypothesis at 0.05 level of significance. The findings showed that teaching further mathematics using Wilson's learning cycle reduces the errors committed by students in logical reasoning. Other findings of the study are discussed.

KEYWORDS: Estimation of Errors, Further Mathematics Students, Remediation

INTRODUCTION

Further Mathematics (FM) as the science of number, quantity and space is applied to other disciplines such as physics, engineering and statistics. Knowledge of Further Mathematics helps to develop the powers of logical reasoning (LR) and problem solving in students. The Nigerian Educational Research and Development Council (NERDC) developed the FM curriculum to reflect continuity with mathematics studied in universities, polytechnics, colleges of education and colleges of science and technology. The aim is to help students develop conceptual and manipulative skills in mathematics, so as to prepare them for further studies in mathematics and its application (NERDC, 2008). It is meant for potential Mathematicians, Engineers and Scientists. Hence, it is recommended for students with high ability in general mathematics that will need to acquire a good foundation for future studies in mathematics or mathematics-related courses. To achieve these objectives, emphasis is placed on the teaching and learning process in the content area and logical reasoning is one of such areas that enhance students' development of their potentials. The report of Education Resource Centre (ERC) on analysis of Senior School Certificate Examination (2011-2015) in Plateau State revealed that there is high rate of failure in

further mathematics occasioned by high errors committed by students. The evidence indicated that the high rate of failure particularly in logical reasoning is traceable to the methods of teaching. In order to overcome the problems of high rate of errors in the subject, the use of effective teaching methods, which could help to reduce the errors students commit was suggested. In this study, the researchers used Wilson's Learning Cycle (WLC) for remediation of errors committed by further mathematics students in logical reasoning. The WLC is a method that exposes the students to motivational activities requiring physical experiences and interaction as a basis to acquiring knowledge. It involves five stages: Initiation, abstracting, schematizing, consolidation and transfer. The use of Wilson's Learning Cycle (WLC) has not been empirically verified in the area of Logical Reasoning (LR).

LITERATURE

In the course of preparing instructional materials for classroom teaching of concepts in science, technology and mathematics (STM), teachers and instructional materials developers bring together ideas about good teaching. They consider the way students learn and the nature of the discipline, which are germane to the efforts towards achieving positive learning outcome. The development of learning cycles is an example of such efforts. Originally learning cycles (LC) was developed in an elementary science program call the Science Curriculum Improvement Study (SCIS). The LC teaching approach involves students in an active learning process modelled on four elements of Jean Piaget's theory of cognitive development. These are physical experience referring to the biological growth of the central nervous system, social interaction, physical maturation and self-regulation, the active process of forming concepts (Barman and Allard, 1993). The LC consists of three phases. The first phase is exploration in which the students are engaged in motivational activities that require physical experience and social interaction to provide a basis for the development of concepts. The second phase is concept introduction. In this phase, the instructor builds on students' exploratory experiences to introduce the main concept of the lesson. The final phase is concept of application. This phase provides students with an opportunity to study additional examples of the main concepts or to challenge themselves with new tasks requiring an explanation from earlier lessons.

Some models of LC have been developed, to enable curriculum planners and teachers to produce workable sequence of instruction in mathematics. These include the Karphill learning cycle, Kolbs' learning cycle, Experiential learning cycle, Wilson's learning cycle, etc. The Wilson's learning cycle (WLC) is an activity-based, exploratory-centred model of instruction based on the Piagetian theory of development as learning that bridges the gap between the expected and actual levels of students reasoning (Mitchell, 1992). Aguele (2004) regards WLC as the process of exploration and application of concepts gained during such investigative activities. Wilson learning cycle is a method of instruction that involves five stages of initiation, abstracting, schematizing, consolidation and transfer (Oduwale and Odiase, 1996). These stages are briefly discussed as follows.

Initiation

At this stage a diagnostic test allows for the strengths and weakness of students to be identified. This is necessary in order to effectively carry out the remediation process. This is done before the actual commencement of the remedial teaching by administering a test (pre-test). The pre-test enables one to ascertain the relative standing of each student before any intervention. At this stage, the day to day lesson actively starts with students using concrete materials to help them solve a problem intuitively. This stage also is congruent with the exploration phase of the Science Curriculum

Improvement Study (SCIS). The exploration phase in the SCIS gives students experiences with the concepts to be developed before they are discussed, read aloud and named (Abraham and Renner, 1986).

The **abstracting** stage is concerned with moving the learning from the concrete to a more complicated level including the use of symbols. During this stage, the concept is named and presented to the students through classroom discussion and activities of students are encouraged to describe or explain the activities. The abstracting stage is followed with **schematizing** (Modeling). The schematizing stage involves helping the students fit new rule into their mental schemes or template and links it to related ideas. During this stage, a scheme or a model, which can be used and re-used to answer such related problem, is developed. **Consolidation** (Practice) is the next stage after schematizing. This stage is intended to make the students gain mastery of the skills they have leant. Students are provided with opportunities for meaningful practice so that the learner will be able to retrieve and use concepts in an automatic and accurate way (Oduwale and Odiase, 1996).

Transfer is the final stage. During this consolidation stage, the teacher identifies students with difficulties. These categories of students are grouped together to transfer or share ideas. If possible the teacher is expected to point out the main areas of worries. It does not necessary mean going over the entire lesson that has been taught but uses different examples to demonstrate the model (Scheme) to the students. This study used Wilson's learning cycle to estimate the errors committed by further mathematics students in logical reasoning and remediation was made.

Problem

Secondary school students' achievement in Further Mathematics is declining, and stakeholders in mathematics education in Nigeria are very concerned about this issue. This declining trend in achievement is attributed to the errors committed by students during internal and external examinations. Detecting and remediating the errors committed by students is one of the ways poor achievement in Further Mathematics can be minimized. However, the question is: how can this be done? This question is pertinent because experiential evidence shows that the errors committed by students when solving further Mathematics problems is still high and learning outcome very low, in spite of the effort by some researchers in the use of different methods and strategies to improve learning. Therefore, the problem of this study put in form of a question is: could the use of Wilson's Learning Cycle (WLC) prove effective for remediation of errors committed by further mathematics students in logical reasoning?

Purpose

The main purpose of the study is to estimate the errors committed by further mathematics students in logical reasoning, and attempt remediation using Wilson's learning. Specifically the study seeks to determine the:

- types of errors frequently committed by FM students in LR,
- effect of WLC on remediation of the errors committed by FM students in LR,
- Influence of gender on remediation of the errors committed by FM students in LR when taught using WLC.

Research Questions

The following research questions were raised to guide the study:

- What are the errors frequently committed by Further Mathematics (FM) students in logical reasoning

(LR)?

- What is the effect of Wilson's Learning Cycle (WLC) on remediation of the errors committed by FM students in LR?
- What is the influence of gender on remediation of the errors committed by FM students in LR when taught using Wilson's Learning Cycle (WLC)?

Hypothesis

The following null hypothesis was formulated and tested at 0.05 level of significance.

Ho_1: There is no significant difference between the mean errors committed by male and female Further Mathematics (FM) students when taught Logical Reasoning (LR) with Wilson's Learning Cycle (WLC).

METHOD

The design of the study is informal experimental design, specifically, before-and –after without control design. Kothari (2004) explains that in before-and-after without control design, 'a single test group or area is selected and the dependent variable is measured before the introduction of the treatment'. The effect of the treatment on the dependent variable is measured at the end of intervention, and would be equal to the difference in level of the phenomenon before and after the intervention. In other words, 'the effect of the treatment would be equal to the level of the error after the treatment minus the level of error before the treatment'. The design is represented as follows:

Test Area:

Level of error before the treatment (LX) — Treatment → Level of error after the treatment (LY)

Effect of Treatment (ET) = (LY) – (LX).

Area of Study

The study was conducted in Northern Education Zone of Plateau State, Nigeria. The zone consists of six (6) Local Government Areas: Bassa, Jos North, Jos South, Jos East, Riyom and Barkin-Ladi. The researchers chose this zone because errors committed by students during internal and external examinations in Further Mathematics are still high. The zone, when compared other education zones in Plateau State, has the highest number of students that offer Further Mathematics and do register the subject in Senior Secondary Certificate Examination (SSCE). The sample for this study consisted of 65 Senior Secondary II students (44 males, 21 females) from four co-educational public secondary schools.

Sample and Sampling Technique

Purposive sampling technique was used to select the schools that have both male and female students who registered for Further Mathematics in senior secondary certificate examination (SSCE). The 2008 Curriculum for further mathematics used in this study consists of the following nine sub-topics in Logical Reasoning: Statements, Negation, Conditional Statements, Compound Statements, Disjunction, Conjunction, Equivalent Statements, Tautology and Contradiction, Laws of the Algebra of Logical Statements.

Instrument

The instrument used to collect data for the study is the Error Remediation Items (ERI). It is an essay test in Logical Reasoning. The questions (test items) were constructed using the senior secondary school II curriculum on further mathematics. The essay test was chosen for its advantage over the objective test in checking guesswork and affording students the opportunity to express their thought processes. It also enables the researchers to detect errors. The essay test consisted of 18 test items. It was constructed based on the scope of the scheme of work for SSII students and all the sub-topics in logical reasoning were adequately covered. A Rubric was also developed by the researchers for marking the test. The Rubric was designed in such a way that different types of errors that could be committed by each student can be detected. The errors were: Symbol error (S), Comprehension error (C), Transformation error (T), Process skill error (P), Encoding error (E) Careless error (CL) and Logical error (L).

Experimental Procedure

The researchers trained four further mathematics teachers for one week on how to use the lesson notes with WLC. Thereafter, the teachers carried out team teaching in a school outside the study area for another one week. This was to ensure uniformity, compliance and effectiveness among the teachers. Each of the four teachers was given a copy of the lesson note and scheme of work to be used in their various schools, in accordance with each school's peculiar timetable. Before treatment commenced with WLC, ERI was administered to the students as pre-test and at the end of the experiment, the teachers who also were research assistants administered again ERI as post-test to the students. The scores obtained from the pretest and posttest were used for data analysis

Data Analysis

Data collected was analyzed using Statistical Package for Social Science (SPSS) version 16. Question 1 was answered using frequency count and percentages; questions 2 and 3 were answered using Mann-Whitney U test and to test the null hypothesis at 0.05 level of significance.

RESULTS

Research Question 1

What are the errors frequently committed by Further Mathematics (FM) students in logical reasoning (LR)?

Table 1: Percentage Errors Frequently Committed By Further Mathematics (FM) Students in Logical Reasoning (LR)

Types of Errors	N	Minimum	Maximum	Sum	Percentage
Symbol Error	65	8.00	16.00	833.00	13.56
Comprehensive Error	65	5.00	20.00	975.00	15.87
Transformation Error	65	8.00	18.00	896.00	14.58
Process Skill Error	65	7.00	15.00	778.00	12.66
Encoding Error	65	7.00	15.00	780.00	12.69
Careless Error	65	9.00	19.00	933.00	15.18
Logical Error	65	5.00	20.00	950.00	15.46

Table 1 shows the percentage errors frequently committed by FM students in LR based on types. From Table 1,

the result indicates that Symbol Error, Comprehensive Error, Transformation Error, Process Skill Error, Encoding Error, Careless Error and Logical Error had 13.56%, 15.87%, 14.58%, 12.66%, 12.69%, 15.18% and 15.46% respectively. The highest error committed by FM students in LR was Comprehensive Error. This is followed by Logical Error, Careless Error, Transformation Error, Symbol Error, Encoding Error and Process Skill Error being the least committed. This is indicative that Further Mathematics (FM) students commit Symbol Error, Comprehensive Error, Transformation Error, Process Skill Error, Encoding Error, Careless Error and Logical Error in logical reasoning (LR).

Research Question 2

What is the effect of Wilson's Learning Cycle (WLC) on remediation of the errors committed by FM students in LR?

Table 2: Mean of Errors Committed by FM Students in LR Before and After Remediation with Wilson's Learning Cycle (WLC)

Errors	N	Before Treatment		After Treatment		Mean Difference
		$\bar{X}$	SD	$\bar{X}$	SD	
Symbol Error	65	12.09	1.55	6.34	1.82	5.75
Compr. Error	65	15.00	2.68	6.50	2.83	8.50
Transf. Error	65	13.31	1.97	5.97	2.43	7.34
Process Skill Error	65	11.22	1.58	5.25	1.87	5.97
Encoding Error	65	11.22	1.58	2.25	1.87	5.97
Careless Error	65	13.88	2.24	6.03	2.65	7.85
Logical Error	65	14.59	2.82	6.13	2.52	8.46
Total Error	65	91.25	13.42	41.47	15.17	49.78

Table 2 shows the mean errors committed by FM students in LR before and after remediation with Wilson's Learning Cycle (WLC). From Table 2 the result indicates that Symbol Error, Comprehensive Error, Transformation Error, Process Skill Error, Encoding Error, Careless Error and Logical Error had before treatment mean values of 12.09, 15.00, 13.31, 11.22, 12.22, 13.88 and 14.59 respectively. The highest error committed by FM students in LR for Wilson's Learning Cycle (WLC) group was Comprehensive Error. This is follow by Logical Error, Careless Error, Transformation Error and Symbol Error. Encoding Error and Process Skill Error had the same mean errors and were the least committed. In addition, after using Wilson's Learning Cycle on the students, the mean errors committed by FM students in LR were 6.34, 6.50, 5.97, 5.25, 2.25, 6.03 and 6.13 for Symbol Error, Comprehensive Error, Transformation Error, Process Skill Error, Encoding Error, Careless Error and Logical Error respectively. The difference between the mean errors committed before and after Wilson's Learning Cycle were 5.75, 8.50, 7.34, 5.97, 5.97, 7.85 and 8.46 for Symbol Error, Comprehensive Error, Transformation Error, Process Skill Error, Encoding Error, Careless Error and Logical Error respectively. The total mean errors committed before treatment with Wilson's Learning Cycle was 91.25 and after instruction it was 41.47. The result in Table 2 indicates that there is reduction of errors committed by FM students in LR after being taught with Wilson's Learning Cycle.

Research Question 3

What is the influence of gender on remediation of the errors committed by FM students in LR when taught using Wilson's learning cycle?

Table 3: Mean of Pre and Post Error Difference of the Influence of Gender on Remediation of the Errors Committed by FM Students in LR When Taught Using Wilson's Learning Cycle

Errors	N	$\bar{X}$	SD
Pre/Post symbol Error Difference	65	5.75	2.31
Pre/Post Compr. Error Difference	65	8.50	3.31
Pre/Post Transf. Error Difference	65	7.34	2.80
Pre/Post Process Skill Error Difference	65	5.97	2.42
Pre/Post Encoding Error Difference	65	5.97	2.42
Pre/Post Careless Error Difference	65	7.84	2.90
Pre/Post Logical Error Difference	65	8.47	3.46
Pre/Post Total Error Difference	65	49.78	18.40

Table 3 shows the mean of pre and post error difference of the influence of gender on remediation of the errors committed by FM students in LR when taught using Wilson's Learning Cycle (WLC). From Table 6 the result indicates that Symbol Error, Comprehensive Error, Transformation Error, Process Skill Error, Encoding Error, Careless Error and Logical Error had mean difference of 5.75, 8.50, 7.34, 5.97, 5.97, 7.84 and 8.47 respectively. The highest error difference of the influence of gender on remediation of the errors committed by FM students in LR for Direct Instruction group was Comprehensive Error. This is follow by Logical Error, Careless Error, Transformation Error, Process Skill Error and Encoding Error, and Symbol Error being the least committed.

Table 4: Mean Rank of Error Difference of the Influence of Gender on Remediation of the Errors Committed by FM Students in LR When Taught Using Wilson Learning Cycle

Errors	Gender	N	Mean Rank	U	Z	Sig
Pre/Post symbol Error Difference	Male Female Total	44 21 65	17.16 14.27	91.00	-0.98	0.33
Pre/Post Compr. Error Difference	Male Female Total	44 21 65	17.05 15.45	104.00	-0.46	0.65
Pre/Post Transf. Error Difference	Male Female Total	44 21 65	17.69 14.23	90.50	-1.00	0.32
Pre/Post Process Skill Error Difference	Male Female Total	44 21 65	17.57 14.45	93.00	-0.90	0.37
Pre/Post Encoding Error Difference	Male Female Total	44 21 65	17.57 14.45	93.00	-0.90	0.37
Pre/Post Careless Error Difference	Male Female Total	44 21 65	16.88 15.77	107.50	-0.32	0.75
Pre/Post Logical Error Difference	Male Female Total	44 21 65	15.93 17.59	103.50	-0.48	0.63
Pre/Post Total Error Difference	Male Female Total	44 21 65	17.17 15.23	101.50	-0.56	0.58

Table 4 shows the mean rank of pre and post error difference of the influence of gender on remediation of the errors committed by FM students in LR when taught using Wilson Learning Cycle (WLC). From Table 4 the result indicates that male students had mean rank of 17.16, 17.05, 17.96, 17.57, 17.57, 16.88 and 15.93 for Symbol Error,

Comprehensive Error, Transformation Error, Process Skill Error, Encoding Error, Careless Error and Logical Error respectively. Female students had mean rank of 14.27, 15.45, 14.23, 14.45, 14.45, 15.77 and 17.29 for Symbol Error, Comprehensive Error, Transformation Error, Process Skill Error, Encoding Error, Careless Error and Logical Error respectively. The influence of gender on remediation of the errors committed by FM students in LR when taught using Wilson Learning Cycle was more predominant for male students in Transformation Error, Process Skill Error, Encoding Error, Symbol Error Comprehensive Error and Careless Error. This is because the male students have the highest mean rank when compared with their female counterparts in these types of errors. It was also observed from Table 4 that the influence of gender on remediation of the errors committed by FM students in LR when taught using Wilson Learning Cycle was more predominant for female students in Logical Error. This is because the female students have the highest mean rank when compared with that of their male counterparts in this type of error.

Ho_1: There is no significant difference between the mean errors committed by male and female Further Mathematics (FM) students when taught Logical Reasoning (LR) with Wilson's Learning Cycle (WLC).

The result in Table 4 also shows the U and Z values with associated probability for each type of error. The associated probabilities were 0.33, 0.65, 0.32, 0.37, 0.37, 0.75 and 0.63 for Symbol Error, Comprehensive Error, Transformation Error, Process Skill Error, Encoding Error, Careless Error and Logical Error respectively. Since the associated probability values for each type of error was greater than 0.05 set as level of significance, the null hypothesis (H_{01}) which stated that there is no significant difference between the mean errors committed by male and female Further Mathematics (FM) students when taught Logical Reasoning (LR) with Wilson's Learning Cycle (WLC) was not rejected. Thus, inference drawn was that there is no significant difference between the mean errors committed by male and female Further Mathematics (FM) students when taught Logical Reasoning (LR) with Wilson's Learning Cycle (WLC).

DISCUSSIONS

Errors Committed by Further Mathematics Students in Logical Reasoning

Based on results presented, errors committed by further mathematics students in logical reasoning are inversely proportional to their achievement. The higher the errors committed the less achievement of students in logical reasoning and the lower the errors committed the greater achievement of students in logical reasoning. This is clearly seen in the sum of frequency and percentage of errors committed by further mathematics students in logical reasoning. Further Mathematics (FM) students committed Symbol Error, Comprehensive Error, Transformation Error, Process Skill Error, Encoding Error, Careless Error and Logical Error in logical reasoning (LR). There was reduction of errors committed by FM students in LR after being taught with Wilson's learning cycle. This finding is in line with Swan (1983), Payne and Squib (1990), Chin in Aguele (2004), Ugwo in Aguele (2004), Usman and Harbor-Peters (1998), Lee (1998), Aguele (2004), Aguele, Omo-Ojugu and Imhanlahimi (2010), Salman (2012), Ekwueme and Ali (2012) among others. These researchers discovered that students commit errors while solving some mathematics problems and when expose to some effective teaching methods the errors were reduces; this lead to higher achievement in the content area under study. From the above assertion, it is certain that there is a strong relationship between instructional method used in this study as students commit more errors before treatment and fewer errors after treatment. Therefore, there is a need for teachers to identify different instructional strategies and utilize them for better achievement.

Errors Committed in Logical Reasoning by Further Mathematics Students Due to Gender

The highest error difference of the influence of gender on remediation of the errors committed by FM students in LR was Comprehensive Error. This is follow by Logical Error, Careless Error, Transformation Error, Process Skill Error and Encoding Error, and Symbol Error being the least committed. The influence of gender on remediation of the errors committed by FM students in LR was more predominant for male students in Transformation Error, Process Skill Error, Encoding Error, Symbol Error Comprehensive Error and Careless Error. This is because the male students have the highest mean rank when compared with their female counterparts in these types of errors. It was equally observed that the influence of gender on remediation of the errors committed by FM students in LR when taught using Wilson Learning Cycle was more predominant for female students in Logical Error. This is because the female students have the highest mean rank when compared with their male counterparts in this type of error. The result of this study supported studies conducted in relation to gender with some studies in favour of males while some in favour of females. Based on the kind of errors, female students commit more while male students commit less and vice versa. This is in line with Oluokun (2002), Aguele (2004), Alade (2006), Okigbo and Osuafor (2008), Madu and Hogan-Bassey (2010), Olarewaju and Awofala (2011), Alade (2012), Education for All-EFA Global Monitoring Report (2012), ERC Jos (2015) among others.

In this study, the grand associated probability values for all types of errors was less than 0.05 set as level of significance, the null hypothesis (H_{O1}) which stated that there is no significant difference between the mean errors committed by Further Mathematics (FM) students when taught Logical Reasoning (LR) with Wilson's Learning Cycle (WLC) was rejected. This implies that there is a significant difference between the mean errors committed by Further Mathematics (FM) students when taught Logical Reasoning (LR) Wilson's Learning Cycle (WLC). Also, the study revealed that the associated probability values for each type of error was greater than 0.05 set as level of significance, the null hypothesis (H_{O1}) which stated that there is no significant difference between the mean errors committed by male and female Further Mathematics (FM) students when taught Logical Reasoning (LR) Wilson's Learning Cycle (WLC) was not rejected. This implies that there is no significant difference between the mean errors committed by male and female Further Mathematics (FM) students when taught Logical Reasoning (LR) Wilson's Learning Cycle (WLC).

IMPLICATIONS TO RESEARCH AND PRACTICE

The results of this study have implication to the teacher; since errors can be committed by anybody, teachers need to prepare and master the content area before coming to the class to teach. This way, error will be minimized to the barest minimum. In a class where the teacher observe that the rate of errors committed in very high, they may use the Wilson's learning cycle to teach sub-topics in logical reasoning to further mathematics students which is capable of yielding good result. The implication of this study to students is that errors committed leads to failure and they will be more careful when attempting questions. Every student wishes to pass examination but commission of more errors lead to failure, which is contrary to what they want. Students should practice more exercises individually and in groups to master the content and asks question where necessary. The implication to the parents is that an avenue has been created for engaging their children meaningfully by providing them with effective teachers who can help them in those areas of the subject, which their wards find difficult. Parents can buy all the necessary textbooks and other learning materials to keep their wards busy as they monitor their day to day activities. The implication to school proprietors, especially the government (ministries of education), teacher training institutions and curriculum planners is that, they should organise workshops and seminars for teachers to improve their teaching methods; provide adequate instructional materials, good libraries, internet facilities,

computers, and adequate funding to primary and secondary school teachers to enable them lay solid foundation for students in mathematics, especially those of them who aspire to study the subject at higher education level.

CONCLUSIONS

On the bases of the findings of this study, the following conclusions are made. All further mathematics students commit errors before and after treatment with Wilson's learning cycle. The errors committed before treatment was higher which leads to lower achievement in logical reasoning while the errors committed after treatment was lower after treatment which leads to higher achievement in logical reasoning by further mathematics students. Although, Wilson's learning cycle was effective on remediation of errors in logical reasoning. In terms of gender with regard to Wilson's learning cycle, there is no significant difference in the errors committed by male and female students. Though, based on types of errors committed, there were some variations. Commission of errors by all students is inevitable, however female students committed fewer errors than their male counterparts did. Wilson learning cycle was found to be effective in the estimation of errors by further mathematics students and remediation of errors in logical reasoning. Another contribution that this study made to knowledge is that towards the understanding that different types of errors are committed by students affect different levels of academic achievement. It is therefore very important that teachers should educate the students to play down on the quest for right answer and highlight the importance of the steps involved in arriving at the correct answer.

RECOMMENDATIONS FOR FURTHER STUDIES

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

- Further mathematics teachers should use Wilson's learning cycle in teaching logical reasoning;
- Schools should provide enough learning materials, and employ capable teachers to teach their students.
- Teachers should go for re-training programmes, cooperate with one another and ensure that some topics are best handled, if need be, by their colleagues who may be better placed to do so.
- Seminars and workshops should be organized by State and Federal Ministries of Education for teachers on those activities in the curriculum that will bring about improvement in learning, acquisition of creative thinking, problem solving and performance skills in students.

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