Problem Based Learning Technique and its effect on Acquisition of Linear Programming Skills by Secondary School Students in Kenya

Shikuku Beatrice Nakhanu[1*] Amadalo Maurice Musasia[2]
1. Masinde Muliro University of Science and Technology, Kenya
2. Masinde Muliro University of Science and Technology, Kenya

Abstract
The topic Linear Programming is included in the compulsory Kenyan secondary school mathematics curriculum at form four. The topic provides skills for determining best outcomes in a given mathematical model involving some linear relationship. This technique has found application in business, economics as well as various engineering fields. Yet many Kenyan secondary schools hardly teach the topic. The methods used are found to be difficult to execute leading to lack of understanding by the learners. The purpose of this study was to investigate whether Problem Based Learning intervention can encourage and improve students' learning of linear programming. Students' performance on an achievement test, and acquisition of linear programming skills were monitored. The study adopted the pre-test, post-test non-equivalent groups experimental design. The experimental group was taught the topic using the origin test and extreme points technique, a version of Problem Based Learning. The control group was taught using conventional methods. A mathematics achievement pre-test and a post-test were given to both groups to ascertain their respective entry and final performance abilities. Analysis of the post-test results was done using the means, standard deviations and paired samples t-test. In addition, item 3 of the mathematics achievement post-test, was used to determine the level of students' acquisition of linear programming skills. The face and content validity of the research instruments were determined with the help of mathematic educators and experienced secondary school mathematic teachers. The split half method was utilized in determining the instruments' reliability acceptable at reliability indices of 0.6. Pearson's coefficient (r) obtained for MAT 1 School 1 was 0.9211 and 0.9131 for school 2. Pearson's coefficient (r) for MAT 2 for School 1 was 0.8786 and for school 2 it was 0.8896. Stratified Random Sampling was used to select ten each of form four boys, girls, and co-educational schools for the study. In total 1,502 form four students participated in the study. Of this total, 745 students formed the experimental while 757 formed the control group.
Keywords: Problem Based Learning Technique, Linear Programming Skills, Pre-requisite knowledge, Secondary School Students, Kenya

1. Introduction

Mathematics plays a vital role in personal, national and global development. It's fundamental role lies in its application in most social sciences like geography, government and business transactions and in house hold chores. In addition, mathematics has been applied within various studies such as engineering, biology, medicine, economics, and in military advancement (Cockcroft, 1982). In Kenya, mathematics is a compulsory subject taught to all learners from primary school up to secondary school level. Apart from English, mathematics is allocated more time on the teaching timetable than any other subject. Learners have reasons to individually study mathematics as it is a requirement in all careers and personal training.

The secondary school mathematics program in Kenya covers a wide range of topics including: Numbers, Measurement, Algebra, Geometry, Trigonometry, Statistics, Probability, Matrices, Three dimension geometry and Linear programming (KIE, 2002). Linear programming is about making maximum benefit or minimum loss out of limited resources in daily life. It deals with maximizing linear variables, subject to linear constraints (Yu, 2007). It is a method of optimizing a given problem with a mathematical model (Ellis, 1983; Togo, 2005; Overtone, 1997). Applications of linear programming date back to 1930 and were first attempted by the Soviet mathematician Leonid Kantorovich and by the American economist, Wasity Leontief in the areas of manufacturing schedules and economics respectively.

The founders of linear programming include George B. Dantzig, who devised the simplex method in 1947, and John von Neumann, who established the theory of duality the same year. The Nobel Prize in economics was awarded in 1975 to the mathematician Leonid Kantorovich (USSR) and the economist Tjalling Koopmans (USA) for their contributions to the theory of optimal allocation of resources, in which linear programming played a key role. Glydon (2010), Yahya (2004) and Khan et al. (2011) look at mathematics beyond the school and observe that: linear programming enables industries and companies to find optimal solutions to economic and production decisions. Linear programming is therefore an important part of operations research and continues to make the world more economically efficient (Mc Namara, 1983; Dantzig, 1998; Fagoyimbo et al, 2012; Yahya et al. 2012).

In the secondary school mathematics syllabus in Kenya, the topic linear programming is taught in the fourth year. However, the prerequisite to linear programming is linear inequalities which are first taught at primary school level. Linear inequalities are revisited in secondary school in form two where students are required to form simple inequalities and graph them. By the end of Form Two, students are expected to draw graphs of simultaneous inequalities, and then describe regions of the plane. In Form Four, they are introduced to linear programming and optimization technique (KIE, 2007). Shikuku (2009) found that linear Programming was not taught by over 90% of schools in Kakamega South District. According to the teachers, the topic was too difficult to teach and was hardly tested by KNEC. An examination of past KCSE mathematics examination papers shows that over the years, test items on linear programming were few and widely spaced (KNEC Reports, 2002 -2010). This contributed to the negative attitude of teachers towards the topic.

2.The problem

Linear programming is one of the topics in KCSE mathematics syllabus that is hardly taught in Kenyan Secondary schools. It is one of the last topics taught in the fourth year just before the KCSE examinations, and when taught, it is only to selected bright students. An examination of KNEC past examination papers in mathematics, clearly indicate that between 2002 and 2010, only 10 out of 352 questions tested linear programming. This accounts for 0.03% of tested examination items over this period of time. Also, the teacher centered methods of instruction used, are often uninteresting, unimaginative, and do not help students to develop the related concepts and skills. Consequently performance in linear programming in secondary schools is wanting. In addition linear programming skills are not mastered by the time the learners leave high school. This study investigated achievements of learners taught using a Problem Based Learning technique in terms of performance, and acquisition of linear programming skills. The origin test and the extreme points technique, which is a version of PBL is suitable in this design and literature has shown that it has been used with success elsewhere. The study compared achievements due to this approach, to those obtained when the conventional methods for teaching linear programming were used.

3. Objectives of the study

(i) To determine the level of linear programming knowledge achieved by learners taught using the origin test and extreme points technique, compared to those taught using conventional methods.

(ii) To analyze the linear programming skills acquired by learners taught using the origin test and extreme points technique compared to those taught using conventional methods.

3.1 Research Hypotheses

HO_1: There is no difference in the level of linear programming knowledge achieved between learners taught using the origin test and extreme points technique and those taught using conventional methods.

HO_2: There is no difference in linear programming skills acquired by learners taught using the origin test and extreme points technique and those taught using conventional methods.

4. Research Design

This study adopted the pre-test, post-test non-equivalent group experimental design. The design involved two groups of subjects, with one group being the control and the other being the experimental group. As Kothari (2004) points out, the pre-test post-test non-equivalent group design, can use existing groups as basis for experimentation. One class from each sampled school constituted one group of subjects. Thirty schools were used. Fifteen schools formed the experimental group and fifteen schools formed the control group. The experimental group was taught using the origin test and extreme points technique while the control group was taught using conventional methods. These conventional methods were the usual trial and error method or the search line method.

4.1Sampling Design

The study employed stratified sampling to select boy schools, girl schools, and co-educational schools. This was followed by simple random sampling to select ten schools from each category for the study. Some of the sampled schools had more than one stream, so simple random sampling was used to select one class that participated in the study. Samples from simple random sampling, yield data that can be used in generalization (Borg, 1987; Mugenda and Mugenda, 1999).

4.2 The Sample

There were 262 secondary schools with about 17000 candidates in Kakamega County. These included national, county, district and private schools. The population for this study was Form Four students registered for KCSE examinations of the year 2013. The sampled schools are shown in table 1.

Table 1: The Sample

School Type	Boys only	Girls only	Co-educational	Total
National	1	1	0	2
County	6	7	6	19
District	3	2	4	09
Total	**10**	**10**	**10**	**30**

The experimental group consisted of 5 boy schools with 249 students, 5 girl schools with 248 students, and 5 co-educational schools with 248 students. The control group consisted of 5 boy schools with 257 students, 5 girl schools with 249 students, and 5 co-educational schools with 251 students. This gave a total of 745 students in the experimental group, and 757 students in the control group. 1052 students took part in the study.

4.3 Research Instruments and Methodology

The purpose of this study was to assess the effect of problem based learning technique on secondary school students' achievement and acquisition of skills in linear programming, a topic in the KCSE mathematics syllabus. To achieve this, two instruments were used, namely: Mathematics Achievement Pre-test (MAT, 1) and Mathematics Achievement Post-test (MAT, 2) MAT 1 had five items that tested linear programming prerequisites namely, construction of linear graphs, ability to form inequalities, graphing the inequalities, shading out the unwanted regions and solving simple simultaneous linear equations by graphical method. MAT 2 also had five items that tested students' performance in linear programming and optimization. This involved application of linear programming skills and concepts to solve problems. The skills included forming inequalities, drawing inequality lines, shading out unwanted regions and finding optimal points.

MAT 1 was administered to both Experimental group (E) and Control group (C) within one week. The experimental group (E) was then exposed to seven (7), 40 minute lessons in linear programming using the origin test and extreme points technique, while the control group (C), was exposed to the same content but using conventional methods. Teaching linear programming took two weeks. On completion, and with the help of research assistants, MAT 2 was administered to both groups E and C within one week.

5. Results and Discussion

Both groups were tested to find out their entry ability on linear programming. MAT 1 tested linear programming prerequisites. This work is expected to be covered in form two, and therefore by second term of form four, all learners will have been taught these prerequisites. The results are shown in Table 2.

Table 2: Pre-Test Mean scores and Std Deviations and t-test

Group type	Mean	N	Std. Deviation	t-test	
				t	Sig. (2-tailed)
Experimental	63.0467	745	5.68040		
Control	65.7267	757	7.50747		
Total	64.3867	1502	6.68161	1.103	.280

The results indicate that the control group performed slightly better than the experimental group. However, to find out if the difference in performance is significant, an Independent Samples t-test was run at alpha level of 0.05. The results indicated that there was no significant difference in achievement between the two groups. The groups were comparable, statistically similar hence suitable for the study

5.1 Students' Performance after Treatment

After both groups had been taught the topic using the two different methods, MAT 2 was administered. The score for each student was recorded and the cumulative mean for each category was calculated. The results for each group are as shown in Table 3.

Table 3: Post Test (MAT 2) Mean scores Std Deviations and t-test

Group type	Mean	N	Std. Deviation	t-test	
Experimental	58.0733	745	4.54163	t	Sig. (2-tailed)
Control	34.9733	757	6.51290		
Total	46.5233	1502	12.97836	20.134	.000

These results indicate that the experimental group performed better than the control group. However, to find out if the difference in performance is significant, and to test the first hypothesis: "HO_1: There is no difference in the level of linear programming knowledge achieved between learners taught using the origin test and extreme points technique and those taught using conventional methods." a t-test was run at alpha level of 0.05. Results give a t-value of 20.134 which is greater than the table value of 2.37 and a significance of 0.000 which is less than 0.05. The two figures indicate a significant difference in the level of achievement between learners taught linear programming using the origin test and extreme points technique, compared to those taught using conventional methods. The hypothesis is rejected. From literature, similar results were obtained at the University of Delaware by the Institute for transforming Undergraduate Education, which received the Hesburg certificate of excellence for implementing PBL in the classroom

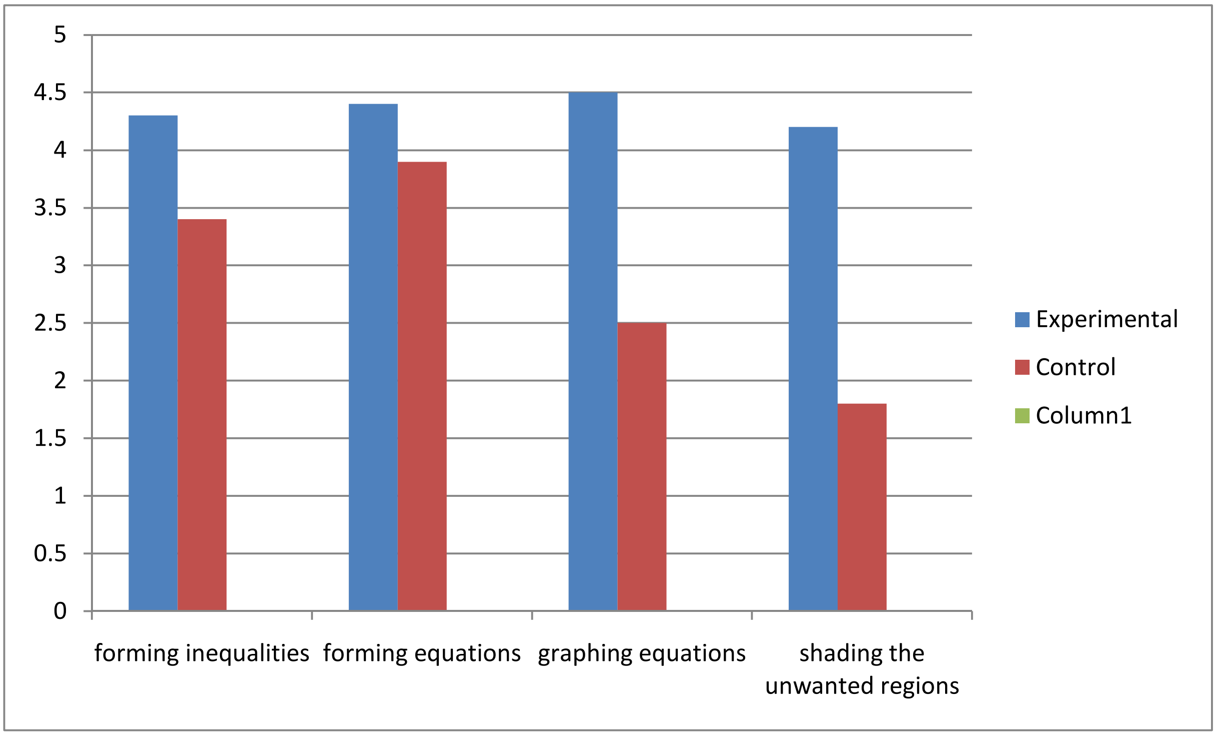
The second objective of the study was to analyze the linear programming skills acquired by learners taught using the origin test and extreme points technique compared to those taught using conventional methods. Item 4 of MAT 2 tested students on the skills of forming linear inequalities, getting a linear equation from the inequality, drawing the graph of such an equation and shading out the unwanted region. The maximum score was 10 marks. Results of the mean score for each group are shown in Table 4.

Table 4: Mean Scores in Skills Learnt, Std Deviations and t-test

Group type	Mean	N	Std. Deviation	t-test	
				t	Sig. (2-tailed)
Experimental	6.3333	745	.22573		
Control	3.8733	757	.69639	28.015	0.000
Total	5.1033	1502	1.35047		

From the table, there is a clear indication that the experimental group acquired the linear programming skills better than the control group. To confirm this indication, and to test the second hypothesis: "HO_2: There is no difference in linear programming skills acquired by learners taught using the origin test and extreme points technique and those taught using conventional methods," a t-test was run at alpha level 0.05. With a t-value of 28.015 which is far greater than 2.37, and a significance of 0.000 < 0.05, the results confirm that in this study, the experimental group acquired the linear programming skills better than the control group. This difference is shown in Table 5.

Table 5: Difference in acquisition of linear programming skills, by the two groups



From Table 5, both groups were able to form inequalities and equations. However the control group found it difficult to differentiate a broken line from a smooth line. They were also unable to shade out the unwanted regions. This is in agreement with the findings of Dantzig (1998), Kariuki and Raburu (1995), and Eshiwani and Chege (1992) as shown in the literature. These results are also in agreement with Riddle (2010), who found out that students have difficulties in forming inequalities that would lead to the solution of a linear programming problem. She says that students cannot interpret simple words like "at least" and "at most" thus ending up with wrong inequalities and wrong solutions. Results of this study have therefore shown that with PBL technique, learners are able to acquire the skills required in the solution of linear programming tasks. The second hypothesis is rejected.

6. Conclusion

Results of this study show that learners taught using PBL achieved better results than those taught using conventional methods. This is in line with results obtained by other authors as indicated in literature (Riddle, 2010, Otunga et al. 1988; Khalagai, 1999). Problem-based learning is a student-centered pedagogy in which students learn about a subject through the experience of problem solving. They learn both thinking strategies and domain knowledge. The goals of PBL are to help students develop flexible knowledge, effective problem solving skills, self-directed learning effective collaboration skills and intrinsic motivation (Hmelo-Silver, 2004, p.2).

These results also show that learners taught using PBL acquired the linear programming skills better than those taught using conventional methods. This is in agreement with Dantzig (1998), who observes that a student needs to identify the objective of the problem, the decision variables and the constraints. The student should then write objective functions and constraints in terms of the decision variables. The student also needs the skill to solve such a problem by first drawing inequality lines on graph paper, and shading out the unwanted regions. This formation is very important to the teacher, who now has a wide range and choice of methods to use when teaching linear programming. This should make linear programming more understandable to learners, and encourage them to accept the topic as it is very useful in daily life activities.

Also, with this information, the curriculum planners KIE will have an opportunity to examine the nature, depth and breadth of coverage of linear programming material, woven into the mathematics curriculum. Issues pertaining to sequencing and timing of coverage should help in improving the presence of linear programming in the KCSE syllabus. This will ensure the topic linear programming is taught to all learners at secondary school, since its usefulness in society has been shown in previous chapters.

REFERENCES

Borg, R.W. (1987) "Educational Research, a practical guide for teachers". *New York*, Macmillan Publishing company.

Cockcroft, W. H. (1982*).* "Mathematics counts: A report of the committee into the teaching of mathematics in schools". *London*: Her majesty's stationary office.

Dantzig, G. B. (1998). "Linear programming and extensions". Princeton University press, (pp 23 -33, ISBN 0691059136)

Eshiwani, G. & Chege, A. N. (1992). "Secondary mathematics Book Four". *The Jomo Kenyatta Foundation:* Nairobi.

Ellis, D. W. and Associates, "Linear programming Consultancy Services". 2220, 142 Ave Edmonton Alta. T5Y 1E6 Canada

Fagoyimbo, I. S. Akinbo, R. Y. Ajibode, I. A, & Olariirah, Y. A, (2010). "Maximization of profits in manufacturing industries using linear programming techniques". Geepee Nigeria Limited. *Proceedings of the first International Technology, Education and Environment Conference, African Society for Scientific Research, (pp 159 – 167)*

Fagoyimbo, I. S. & Ajibode, I. A, (2010). "Application of linear programming techniques into effective use of resources for staff training". *Journal of Emerging trends in Engineering and applied Sciences*. (vol 1 No. 2 pp 127 – 132)

Glydon, N. (2011). "Mathematics Beyond School" http://www.mathcenral.uregina.ca

Hmelo-silver, C.E. (2004). "Problem-based learning: What and How Students Learn". *Educational Psychology Review*,(16(3), 235-266).

Yu, J. Y. (2007). "Lecture notes Trinity Term 2007": University of Oxford

Kariuki, R. & Raburu, G. (1995). "KCSE Revision Mathematics Kenya Literature Bureau": Nairobi.

Kenya Institute of Education, (KIE), (2002). "The secondary school syllabus, volume (ii)": *Government Printers*, Nairobi.

Kenya Institute of Education, (KIE), (2007). "Secondary school mathematics, form Four pupils book". *Kenya Literature Bureau*, Nairobi.

Kenya National Examinations Council, (KNEC), (2000a*).* "Secondary School Examinations syllabus", Nairobi: *Kenya Literature Bureau*

Kenya National Examinations Council, (KNEC), (2005). "KCSE Report 2005", Nairobi: KCSE.

Kenya National Examinations Council, (KNEC), (2008). "KCSE Report 2008", Nairobi: KCSE

Khalagai, E.W. (1996). "Secondary schools pupils errors in algebra and teacher strategies in identifying and counteracting the errors": *Unpublished Doctoral Thesis.* University of Leeds, UK

Khan, I. U., Bajuri, N. H. & Jadoon, I. A. (2011). "Planning for ICI Pakistan using Linear Programming and Sensitivity Analysis". *International Journal of Business and Social Sciences,* 2 (23) 206 -212

Kothari, C. R. (2004). "Research methodology second revised edition": New International Publishers, New Delhi.

Mc Namara, J. F. (1983). "Mathematical programming models in educational planning". Operations Research and its application in educational management 2 (4) 193 – 204.

Mugenda, O. M. & Mugenda, A.G. (2003). "Research Methods, Qualitative& Quantitative Approaches": Acts Press Nairobi.

Otunga, M. (1998). "Secondary School Mathematics book 2": Heinemann Kenya Limited, Kijabe Street, Nairobi

Overtone. M. L (1997). "Draft for Encyclopedia Americana": December 20, 1997

Riddle, E. J. (2010). "Introducing the Formulation of linear Programming Models" Winthrop University, Rock Hill.

Shikuku, B. N. (2009). "Effect of Syllabus coverage on student performance in Mathematics: A case of Kakamega South district, Kenya". *Unpublished Thesis*, Masinde Muliro University of Science and Technology

Togo, D. F. (2005). "Integrating Optimum management into cost systems; An accounting approach to linear programming". *Journal of Business case studies,* 1 (4) 27 – 32

Yahya, W. B. (2004). "Determination of optimum product mix at minimum raw material cost, using linear programming". *Nigeria journal of Pure and Applied Sciences* 19 .(1) 1712 - 1721

Yahya, W. B., Gaaba, M. K., Ige, S. O. & Adeyosoye, A. E. (2012). "Profit maximization in a product mix Company using linear programming". *European Journal of Business management.* 4 (17) 139 - 143