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Application of Linear Programming Knowledge and Skills to Real Life Contexts by Secondary School Students in Kenya

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Authors' contributions

This work was carried out by author SBN under the supervision of authors WWT and KN. Author SBN designed the study, wrote the protocol, and wrote the first draft of the manuscript under the supervision of authors WWT and KN. Author SBN also managed the literature searches, managed the experimental process and analyzed the results. All authors read and approved the final manuscript.

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ABSTRACT

Linear programming is a specific class of mathematical problems, in which a linear function is maximized (or minimized) subject to given linear constraints. Linear programming can be used in a variety of business problems including: transportation and distribution, production scheduling, financial and tax plan, human resource planning, facility planning and fleet scheduling [1,2]. Yet many Kenyan secondary schools hardly teach this topic. The purpose of this study was to investigate whether using the origin test and extreme points technique can encourage and improve students' learning of linear programming. Students' performance on an achievement test, and application 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. In the pre-test, the experimental group had a mean score of 63.05%, while the control group had a mean

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score of 65.73%. An independent samples t-test gave a significance of 0.280 which is greater than 0.05, and a t value of 1.103 which is less than the table value of 2.37. This implied that the two groups had statistically similar entry behavior. Analysis of the post-test results gave a mean score of 58.07% for the experimental group, and 34.97% for the control group. A paired samples t-test gave a significance of 0.000 and a t value 20.13, implying a significant difference in performance between the two groups. In addition, the marks scored in item 3, and item 5 of the post-test, were used to determine the level of students' application of linear programming skills. The mean score for these two items was 60.80 for the experimental group and 34.53 for the control group. A paired samples t-test gave a significance of 0.000 and a t value of 22.456, implying the experimental group was able to apply the linear programming skills significantly better than the control group. Two schools in Kakamega County were used to pilot the study. The face and content validity of the research instruments were determined with the help of mathematics educators and experienced secondary school mathematics teachers. The split half method was utilized in determining the instruments' reliability. Pearson's coefficient (r) obtained for MAT 1 and MAT 2 in the two schools was above 0.88. 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 respondents participated in the study.

Keywords: Linear programming skills; application; 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 [3]. 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 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 (Kenya Institute of Education) [4]. 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 [5]. It is a method of optimizing a given problem with a mathematical model [1,2]. 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 of 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 Yahya and Khan et al. [6,7,8], 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 [9,10,11,12].

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 in standard eight. Linear inequalities are revisited 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 [13]. Shikuku found that linear Programming was not taught by over 90% of schools in Kakamega South District [14]. According to the teachers, the topic was too difficult to teach and was hardly tested by Kenya National Examinations Council (KNEC). An

examination of past Kenya Certificate of Secondary Education (KCSE) mathematics papers indicates that over the years, test items on linear programming were few and widely spaced [15,16,17].

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 [15,16,17]. 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 they 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 the origin test and extreme points technique in terms of performance, and application of linear programming skills to real life contexts. The technique entails a well structured design of a given problem that enables learners to actively engage in finding the solution. The origin test and the extreme points technique is a version of problem based learning, and literature has shown that it has been used with success elsewhere. The study compared these achievements to those obtained when the conventional methods for teaching linear programming were used.

2.1 Objectives of the Study

(i) To examine 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 assess the level of application of linear programming knowledge and skills to real life contexts by learners taught using the origin test and extreme points technique compared to those taught using conventional methods.

2.2 Research Hypotheses

HO_1: There is no significant 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 significant difference in level of application of linear programming knowledge and skills to real life contexts by learners taught using the origin test and extreme points technique and those taught using conventional methods.

2.3 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 points out, the pre-test post-test non-equivalent group design, can use existing groups as basis for experimentation [18]. One class from each sampled school constituted one group of subjects. Thirty schools were used such that 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 either the trial and error method, or the search line method.

2.4 Sampling 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 [19,20].

2.5 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 included two national schools, nineteen county schools and nine sub county schools. The experimental group consisted of 5 boy schools, 5 girl schools, and 5 co-educational schools. The control group consisted of a similar number and type of schools.

2.6 Research Instruments

The purpose of this study was to assess the effect of using the origin test and extreme points technique on secondary school students' achievement and application of linear programming knowledge and skills to real life contexts. 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 like; construction of linear graphs, ability to form inequalities, graph the inequalities, shade out the unwanted regions and solve 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 real life problems. The skills included forming inequalities, drawing inequality lines (smooth or broken), shading out unwanted regions and finding optimal points that would give maximum benefit at minimum cost.

2.7 Data Collection

Both groups were tested to find out their entry ability on linear programming. 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. On completion, and with the help of research assistants, MAT 2 was administered to both groups E and C within one week.

3. RESULTS AND DISCUSSION

The prerequisites to linear programming are expected to be covered in form two, and therefore by second term of form four, all learners had been taught these prerequisites. MAT 1 tested the prerequisites and the results are shown in Table 1.

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.

3.1 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 2.

Table 1. Pre-test mean scores Std deviations and t-test

Group type	% Mean	N	Std. deviation	t-test for equality of means	
Experimental	63.0467	745	5.68040	T	Sig. (2-tailed)
Control	65.7267	757	7.50747		
Total	64.3867	1502	6.68161	1.103	.280

Table 2. Post test (MAT 2) mean scores Std deviations and t-test

Group type	% Mean	N	Std. deviation	t-test for equality of means	
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 significant 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 paired samples 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.

The second objective of the study was to assess the level of application of linear programming knowledge and skills to real life contexts, by learners taught using the origin test and extreme points technique compared to those taught using conventional methods. Items 3 and 5 of MAT 2 were used for this purpose. Thus the mean score in items 3 and 5 for each respondent was calculated and the mean score for each group recorded. Item 3 required the learners to prepare a good quality drink (orasquash) at minimum cost. This involved choosing the ratio of oranges to passion fruits, while considering the cost of each of the fruits. Item 5 required them to transport a maximum number of football fans to Uganda at minimum cost. They had available, 40 seater and 50 seater vehicles each with a cost attached. Results of the mean score for each group are shown in Table 3.

From the table, there is a clear indication that the experimental group applied the linear programming skills better than the control group. To confirm this indication, and to test the second hypothesis: "HO_2: There is no significant difference in the level of application of linear programming skills by learners taught using the origin test and extreme points technique and those taught using conventional methods," a paired samples t-test was run at alpha level 0.05. With a t-value of 22.456 which is far greater than the table value of 2.37, and a significance of 0.000<0.05, the results confirm that in this study, the experimental group applied the linear programming skills in solving real life problems better than the control group. The second hypothesis is rejected.

3.2 Significance of the Study

In terms of their practical value, the findings of this study increase awareness about learning and assessment of linear programming. The instruction technique increases the range and choice of methods to be used hitherto. In terms of contribution to theory, the findings have shade more light on the existing knowledge of linear programming, especially in its application in daily operations in life such as maximize on outputs, and save on inputs like cost, time and space. This is a very important result, because linear programming has been applied in various fields since World War II [2,21,22]. In this study, learners who were taught linear programming using the origin test and extreme points technique developed a higher level of applying linear programming knowledge and skills better than their counter parts who were taught using conventional methods. This is also in agreement with the findings of Dantzig, Kariuki and Raburu Eshiwani and Chege and Riddle, as shown in the literature [10,23,24,25]. Results of this study have therefore shown that with the origin test and extreme points technique, learners are able to apply linear programming skills in the solution of linear programming tasks better than those taught using conventional methods.

Table 3. MAT 2 Item 3 and 5 mean scores Std deviations and t-test

Group type	% Mean	N	Std. deviation	t-test for equality of means	
Experimental	60.800	745	3.2558	T	Sig. (2-tailed)
Control	34.533	757	8.4842	22.456	0.000
Total	47.667	1502	11.7400		

4. CONCLUSION

Results of this study show that learners taught using the origin test and extreme points technique achieved better results than those taught using conventional methods. This is in line with results obtained by other authors as indicated in literature [25,26,27]. This technique is a version of Problem-based learning (PBL), and 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 [28].

These results also show that learners taught using the origin test and extreme points technique applied linear programming skills better than those taught using conventional methods. This is consistent with the findings of Ellis and Togo, [1,2], who showed that linear programming, can be applied in business problems including: transportation and distribution, production scheduling, financial and tax plan, human resource planning, facility plans and fleet scheduling. It is for this reason that learners should be encouraged to study linear programming, teachers to make an effort to teach the topic and KNEC be encouraged to give due consideration to linear programming given its importance in its application in real life situations. 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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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