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"Global Goals, Local Actions: Looking Back and Moving Forward"

## Using Infographics to Enhance Grade 12 Students' Mathematical Communication Abilities in Learning Linear Programming

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### Abstract

This classroom action research examined the effectiveness of using infographics for mathematical communication skills in learning linear programming. The purposes were (1) to enhance students' learning achievement; and (2) to study students' self-confidence in learning mathematics. The participants were 31 grade twelve students studying in the Additional Mathematics course which were purposively selected. Research instruments consisted of eight lesson plans for twelve periods in the 'Linear Programming' topic, pretest, posttest, and student's self-confidence questionnaire. Data was collected regarding students' pretest and posttest scores and students' responses in self-confidence questionnaire.

The results of this action research showed that (1) the effectiveness with respect to student achievement after being instructed had an effectiveness index (E.I.) score of 0.6816 which means students' achievement had increased by 68.16% comparing with their basis; and (2) Student opinion towards the instruction helped their confidence in learning mathematics is at 'Strongly Agree' (45.48%), 'Agree' (44.19%) and 'Disagree' (10.32%).

**Keywords:** MATHEMATICAL COMMUNICATION SKILLS/ LINEAR PROGRAMMING/ INFOGRAPHICS

### บทคัดย่อ

งานวิจัยชั้นเรียนครั้งนี้ได้ตรวจสอบประสิทธิผลของการใช้อินโฟกราฟิกสำหรับทักษะการสื่อสารทางคณิตศาสตร์ในการเรียนเรื่องกำหนดการเชิงเส้น จุดประสงค์ของการทำวิจัยคือ (1) เพื่อพัฒนาผลสัมฤทธิ์ทางการเรียนของนักเรียนและ (2) เพื่อศึกษาความเชื่อมั่นในตนเองของนักเรียนในการเรียนคณิตศาสตร์ นักเรียนที่เข้าร่วมการวิจัยครั้งนี้เป็นนักเรียนชั้นมัธยมศึกษาปีที่ 6 ที่ได้รับการสุ่มตัวอย่างแบบเฉพาะเจาะจง จำนวน 31 คน ซึ่งศึกษารายวิชาคณิตศาสตร์เพิ่มเติม เครื่องมือที่ใช้ในการวิจัยประกอบด้วยแผนการสอน 8 แผน สำหรับการเรียน 12 คาบ ในหัวข้อกำหนดการเชิงเส้น แบบทดสอบก่อนเรียน แบบทดสอบหลังเรียน



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และแบบสอบถามความเชื่อมั่นในตนเอง ข้อมูลที่รวบรวมเป็นข้อมูลจากคะแนนการสอบ ของแบบทดสอบก่อนเรียนและหลังเรียน และการตอบของนักเรียนในแบบสอบถามเกี่ยวกับความเชื่อมั่นในตนเอง

ผลการวิจัยพบว่า (1) ประสิทธิภาพของการใช้อินโฟกราฟิกสำหรับทักษะการสื่อสารทางคณิตศาสตร์ เพิ่มผลสัมฤทธิ์ของนักเรียนหลังการสอนด้วยค่าดัชนีประสิทธิผล (E.I.) เท่ากับ 0.6816 ซึ่งหมายความว่าผลสัมฤทธิ์ของนักเรียนเพิ่มขึ้น 68.16% จากความรู้เดิม และ (2) ความคิดเห็นของนักเรียนที่มีต่อการสอนด้วยวิธีนี้ช่วยให้มีความเชื่อมั่นในตนเองในการเรียนคณิตศาสตร์ในระดับความคิดเห็น ดังนี้ ‘เห็นด้วยอย่างยิ่ง’ (45.48%), ‘เห็นด้วย’ (44.19%) และ ‘ไม่เห็นด้วย’ (10.32%)

**คำสำคัญ:** ทักษะการสื่อสารทางคณิตศาสตร์ / กำหนดการเชิงเส้น / อินโฟกราฟิก

## Introduction

The topic of linear programming is included in the Basic Core Curriculum 2008 (Mathematics). The topic has been found applications in industry, commerce, management science etc. Linear programming is about optimization problems which involve finding maximum value (profit), minimum value (cost), or minimum use of resources, etc. However, many students had some difficulties in learning this topic such as defining the variable to construct the mathematical model of objective function or simply made errors due to the lack of attention on writing the non-negativity constraints. Using a traditional teaching method involving the direct instruction, it is difficult to encourage students to think, discuss, or write the processes of their thoughts because of the limited time and unfavorable environment.

Based on the researcher's pre-practicum experiences at one school in Bangkok, students in various grades have less opportunity to communicate mathematically and present mathematical concepts in their classrooms. It obstructed students from getting familiar with mathematical language, which is essential to the further studying in higher levels.

Communication skills in mathematics are essential in developing mathematical understandings and developing mathematical language skills. These skills have been indicated in the learners' key competencies in the Basic Education Core Curriculum and Stand 6: Mathematical Skills and Processes (The Ministry of Education Thailand, 2008). Furthermore, communication-rich environments help students extend their knowledge and encourage them to think reasonably in mathematics and demonstrate the results of their thinking to others orally or in writing.

For this action research, mathematics was allocated 4 periods per week on the teaching timetable. The researcher, as a pre-service teacher, was informed about the grade twelve students' difficulty in learning the linear programming topic. The prior study of this



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action research found that some students need to improve knowledge and skills in solving linear equations and inequalities which are the prior knowledge and skills in learning linear programming. From various studies, using visualization including infographics can improve students' achievement and mathematical communication skills (Veřmiřovský, 2013; Bicen & Beheshti, 2017)

### Objectives

1. To enhance students' achievement in learning linear programming by using infographics for mathematical communication skills.
2. To study students' self-confidence in learning mathematics by using infographics for mathematical communication skills.

### Research Scope

1. The population used in the classroom action research included ten grade twelve classes (226 students) studying at one public practicum school in Bangkok. The 31 participants in this study were purposively selected from those who studied in the Additional Mathematics Course (assigned by host supervisor of the school).
2. The variables were (1) Independent variable: using infographics for mathematical communication skills in linear programming, and (2) Dependent variables: students' achievement and self-confidence.
3. The duration of this study was 12 periods in the first semester, academic year 2018.

### Literature Review

#### The importance and concepts of linear programming

*Linear programming* is the mathematical formulation of problems in planning and management usually be used for 'optimization problems' which requires to maximize or minimize an '**objective function**' subject to '**constraints.**' It can be used for allocating the limited available resources such as material, money, manpower, space or time to find the best possible solution in business, industry, science, transportation, etc.



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*A firm manufactures two types of box, each requiring the same amount of material. They both go through the folding machine and a stapling machine. Type A boxes require 4 seconds on the folding machine and 3 seconds on the stapling machine. Type B boxes require 2 seconds on folding machine and 4 second on the stapling machine. Each machine is available for one hour. There is a profit of  $\text{฿}40$  on Type A boxes and  $\text{฿}30$  on Type B boxes.*

- a) *How many boxes of each should be produced one hour for maximize profit?*
- b) *What is the profit?*

In the context of this study, the scope of Basic Education Core Curriculum 2008 (Mathematics) requires the students to solve linear programming problems (LPP) by using algebraically method and graphical method. As a consequence of this scope for grade twelve contents, the LPP used in learning and teaching of this topic will be limited to solve LPP involving two decision variables. An example of a linear programming problem was used in this study to describe the components of LPP as the followings.

This problem was used to ask students illustrate their mathematical processes and skills such as ‘communication skills’ which require the students to read and interpret mathematical word problem and ‘representation skills’ which require the students to use a letter for a variable, a symbol of operation for algebraic expression/equation/inequalities, graphs of ‘objective function’ and ‘constraints’.

The evidence from the mathematics education literature demonstrated that students had misconceptions in their prior knowledge and processes. It would be the task of the mathematics teachers to determine the readiness of students and design learning activities to engage students for developing their achievement.

#### **Mathematical communication skills**

For the learners’ quality after graduating Grade 12 (The Basic Education Core Curriculum B.E. 2551 (A.D. 2008), 2008, p. 65), the last point remarks that students should be able to use mathematical language and symbols for communication; can communicate and present mathematical concepts accurately and clearly; link various bodies of mathematical knowledge, principles, and processes with other disciplines; and have attained ability for creative thinking.

According to The National Council of Teachers of Mathematics : NCTM (2000), the communication abilities of students are:

1. Organize and collect mathematical thinking through communication.
2. Communicate their mathematical thinking logically and clearly.
3. Analyze and evaluate the mathematical thinking and strategies that are used by the others.



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4. Use the mathematical language to express mathematical ideas correctly.

In addition, "Writing is valuable way of reflecting on and solidifying what one knows, and several kinds of exercises can severe this purpose ... Using these skills will in turn help students develop deeper understandings of the mathematical ideas about which they speak, hear, read, and write" (NCTM, 2000)

In this study, the researcher designed learning activities by applying only the last three items of four in students' communication abilities. The communication skills in solving LPP mentioned in Section 'The importance and concepts of linear programming' were described in Table 1.

In Table 1, the example describes the steps of formulating LPP model. The word 'one hour' must be converted into '3600 seconds'. The next section will examine the visual approach to help students deeply understand how to solve LPP.



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Table 1 Communication skills in linear programming problems (LPP)

Steps	Descriptions										
1. Identify the variables involved	$x$ = number of Type A boxes made 1 hour $y$ = number of Type B boxes made 1 hour										
2. Determine the objective function	Max of the profit $P$ : $P = 40x + 30y$										
3. Determine the constraints	Number of Type A boxes: $x \geq 0$ Number of Type B boxes: $y \geq 0$ Folding machine time: $4x + 2y \leq 3600$ Stapling machine time: $3x + 4y \leq 3600$										
4. Represent the constraints on a graph and determine the feasible region.											
5. Find the solution	<p>Substitute the value of each vertex <math>(x,y)</math> in the objective function and select the optimal solution.</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Vertex</th> <th><math>P = 40x + 30y</math> (Maximize)</th> </tr> </thead> <tbody> <tr> <td><math>(0,0)</math></td> <td><math>P = 40(0) + 30(0) = 0</math></td> </tr> <tr> <td><math>(900,0)</math></td> <td><math>P = 40(900) + 30(0) = 36,000</math></td> </tr> <tr> <td><math>(0,900)</math></td> <td><math>P = 40(0) + 30(900) = 27,000</math></td> </tr> <tr> <td><math>(720,360)</math></td> <td><math>P = 40(720) + 30(360) = \mathbf{39,600}</math></td> </tr> </tbody> </table> <p>The company should produce 720 boxes for type A and 360 for type B then they will receive the highest profit which is ฿39,600.</p>	Vertex	$P = 40x + 30y$ (Maximize)	$(0,0)$	$P = 40(0) + 30(0) = 0$	$(900,0)$	$P = 40(900) + 30(0) = 36,000$	$(0,900)$	$P = 40(0) + 30(900) = 27,000$	$(720,360)$	$P = 40(720) + 30(360) = \mathbf{39,600}$
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## Infographics

Infographic (Information graphic) is a way to present a specific information by combining with the numbers, symbols, and graphs. Infographic helps to communicate easier and faster since people consume picture faster than text. An effective infographic can turn complicated and boring data to be attractive which simply explain the definition of infographics in Figure 1 (mmdebbys, 2016).

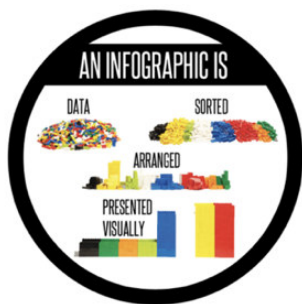


Figure 1 Simple Definition Using infographic (mmdebbys, 2016)

Figure 1 illustrates how infographic is working which started by collecting all the data then categorize or sort the data. After that, arrange each type of data. In this step, there should be using header for subtopics with brief text and present it visually by using graphs, icons, etc. in the final step.

McGuire (2018) introduced nine types of infographics: (1) Statistical infographics—using various data visualizations such as charts, pictographs, etc., (2) Informational infographics—using specialized data visualizations for overview a topic, (3) Timeline infographics—using central time line with branches of different dates or events, (4) Process infographics—describing the overview of the steps in a process which has straightforward layout with numbered step, briefs descriptions and some explicit illustrations, (5) Geographic infographics—using maps as the main visual to present or compare statistics data, (6) Comparison infographics—using a line in the middle, vertically, horizontally or even diagonally to compare and contrast options and to weight pros and cons, (7) Hierarchical infographics—using flowcharts or pyramid to illustrate hierarchies or organizations (8) List infographics—using icons, numbers, bullet points but each item can be switched, (9) Resume infographics—describes personal information about work experience, skills, education.

In this study, the researchers selected two types of infographics: ‘Informational Infographic’ and ‘Process Infographic’. Besides, the researchers are using the Geometer’s Sketchpad (GSP) to create information infographic.

### Learning Achievement, Effectiveness and Self-Confidence

Moyana (1996) and Suleman with Hussain (2016) had collected meaning of achievement that was defined in many ways while Moyana’s own summarized the definition of mathematics achievement as the performance of the students in mathematics that can be measured by the number of scores obtained in mathematics tests or examinations. Van



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den Aardweg and Van den Aardweg (1988 as cited in Moyana) clarified as “a product which can be measure by means of achievement tests and usually associated with mental success”.

The students’ mathematics achievement has a potential impact on the performance or future work in the university and work life (Wilkins & Ma, 2002 as cited in Ma, Bradley, 2009) There are numerous factors that affect students’ mathematics achievement which some of those are classroom environment, teacher’ attribution, students’ attitudes toward mathematics, anxiety including self-confidence (Al-Agili, etal., 2012 and Das, Halder, Bairagya, 2014).

In this study, learning achievement referred to the value of the effectiveness index enhancing students’ mathematics communication abilities while

## Methodology

### 1. Research methodology

This research is a quantitative and qualitative action research to improve students’ achievement and written mathematics communication in learning ‘Linear Programming’ and to study students’ self-confidence.

### 2. Research process

The researchers developed 12-period lesson plans emphasized informational infographic (Figure 2), process infographic (Figure 3) and the activities for practicing mathematical communication skills in learning ‘Linear Programming’.

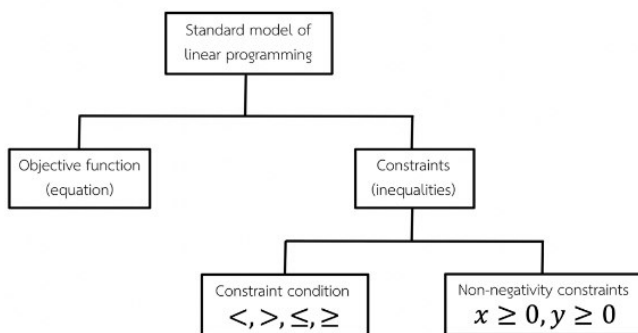


Figure 2 Informational Infographic

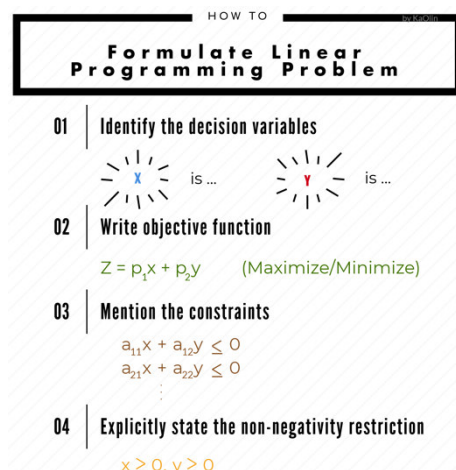


Figure 3 Process Infographic



3. Data collection

The researchers collected the pretest and posttest scores in the topic of linear programming and student’s Mathematics self-confidence questionnaire.

4. Data analysis

The researchers analyzed the collected data (pretest and posttest scores) by calculating the effectiveness index (E.I.) as the following formula (Kidrakan, 2002):

$$E.I. = \frac{P_2 - P_1}{Total - P_1} \quad \text{(Equation no.1)}$$

Where; *E.I.* is an effectiveness index,  
*P<sub>1</sub>* is the sum of all student’s score from pretest,  
*P<sub>2</sub>* is the sum of all student’s score from posttest,  
*Total* is the product of the number of students and the full score of the test.

Students’ responses on mathematics self-confidence questionnaire were analyzed by calculating the percentage of students’ self-confidence in each level (4 means Strongly Agree, 3 means Agree, 2 means Disagree, and 1 means Strongly Disagree).

**Research Finding**

**Objective 1:** The results of data were analyzed by using E.I. as shown in Table 2.

Table 2 Effectiveness Index (E.I.) of students’ achievement

List	Sum of students’ achievement	Effectiveness Index
Pretest score	414	$E.I. = \frac{977 - 414}{1240 - 414} = 0.6816$
Posttest score	977	
Total score	1240	

Table 2 presents results of calculation of E.I. for students’ achievement by substituting into Equation no.1 with the value of the sum of pretest (414), posttest scores (977), and the product of number of students and full score of tests (1240). The value of E.I. is 0.6816.

**Objective 2** The results of data were analyzed by calculating the percentage of each response for all number of statements as shown in Table 3

Table 3 shows the percentage of students’ responses to the level of agreement on 10 statements for self-confidence. The most student response on ‘Strongly Agree’ and ‘Agree’ which indicates the accomplishment of usage of infographics in learning mathematics and no one respond ‘Strongly Disagree’ on any statement.



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## Results and Discussion

The results from the test showed that using infographics can improve students' mathematical communication skills in learning linear programming for with  $E.I. = 0.6816$  that is higher than the acceptance criteria (0.50) which indicates students had gained the knowledge after instruction by 68.16%. Additionally, the results from questionnaire specified how infographics impact on students' self-confidence in learning mathematics. The effectiveness of using infographics in this study is consistent with previous studies which confirmed effectiveness in improve students' achievement and affect mathematical communication skill (Veřmiřovský, 2013; Bicen & Beheshti, 2017).



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Table 3 Percentage of students' responses of self-confidence in learning mathematics

Statement	Strongly Agree (%)	Agree (%)	Disagree (%)	Strongly Disagree (%)
1. I see the importance to learn mathematics.	48.39*	45.16	6.45	0.00
2. I learn better in mathematics.	58.06*	41.94	0.00	0.00
3. I can solve problems reasonably and correctly	51.61*	41.94	6.45	0.00
4. I can learn mathematics quickly.	51.61*	35.48	12.90	0.00
5. I can connect mathematical concepts in a hierarchical way.	45.16	48.39*	6.45	0.00
6. I can apply mathematical representation by using symbols and graphics.	45.16*	38.71	16.13	0.00
7. I do not feel anxiety in learning mathematics.	38.71	41.94*	19.35	0.00
8. I can to explain mathematics contents to other students.	38.71	48.39*	12.90	0.00
9. I can learn contents and strategies to solve problems better than other subjects.	35.48	51.61*	12.90	0.00
10. I can use Infographic to summarize the concepts creatively.	41.94	48.39*	9.68	0.00

Remark \* Indicate students' highest agreement of each statement.

### Suggestions

In this study, the researcher had used purposive sampling and the amount of participants was not enough to describe other populations. Hence, the topic that was used in this study is just only linear programming and there was no comparison with different approaches. For further study, Infographics can be applied to other topics of mathematics or any subjects.

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