

## Classification of Examination Marks according to Bloom's Taxonomy by Using Binary Linear Programming

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**Abstract.** Bloom's Taxonomy was originally created by Benjamin Bloom for categorizing and classifying levels of intellectual learning that commonly occur in examination questions. One of the tools that can be used to assess the level of ability of the students is examination. The difficulty level of each question in the examination is determined from the criteria of keyword found in the question which mainly referred from all of the complexity level of Bloom's Taxonomy. The aims of this study are to evaluate the examination questions, to determine the optimal marks and to setup which complexity level will be applied for tested questions in order to comply with the Bloom's Taxonomy in engineering mathematics course. By developing Model A and Model B, binary linear programming was used to create optimal marks structure of examination questions. The classification of the examination questions marks using these models show that, they satisfied the requirements of complexity cognitive levels in Bloom's Taxonomy and at the same time fulfilled the mark constraints for each sub topics that needed depending on the teaching periods.

**Keywords:** Bloom taxonomy, Examination questions, Linear programming

### 1. Introduction

Examination is one of the common methods to assess the level of knowledge of the students. In order to improve the quality of teaching, it is believed that teacher must be able to set good or proper questions to test the students in the examination. A good and reasonable examination paper must consist of various difficulty levels questions to test different capabilities of students. The difficulty level of each question in the examination paper is determined from the criteria of keyword found in the questions [1-2].

While designing the suitable questions for examination's paper, various criteria need to be considered. Cognitive domain of Bloom Taxonomy is one of them. Bloom's Taxonomy (BT) was originally created by Benjamin Bloom in 1956 for categorizing and classifying levels of intellectual learning that commonly occur in examination questions [3]. BT identified 3 domains of educational activities: cognitive, psychomotor and affective. As mentioned before, we only considered cognitive domains in this study. There are knowledge, understanding, application, analysis, synthesis and evaluation in cognitive process dimensions.

From BT, successive levels can be divided to two groups (lower and higher) with different assessment between them. In BT level, "synthesis, evaluation and analysis" will be referred to as HOT (Higher Order Thinking) and "knowledge and comprehension" will be referred to as LOT (Lower Order Thinking). Application level defined in both groups of taxonomy level. At application level of taxonomy, students are expected to show their ability in "knowledge and comprehension" levels. Since the engineering mathematics I is a subject for first semester students, the highest cognitive level is application. Thus, cognitive levels that will be tested in the examination questions are knowledge, understanding and application level only.

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Since Bloom taxonomy is a classification system of educational objectives based on the level of understanding of the students which is necessary for students achievements in the followed subjects, Thus BT was used by lecturers to setup and construct the examination question types in order to fulfill the requirements of BT [4-6].

The purpose of this study is to evaluate the examination questions, to determine the optimal marks and to setup which complexity level will be applied for tested questions in order to comply with the Bloom's Taxonomy in engineering mathematics I course. There are two models that will be presented based on Engineering Mathematics I which is classified as a compulsory subject for first year students in engineering programs.

## 2. Model Development

In this study two models of examination questions developed, namely Model A and Model B. The models were running by using linear programming. All chapters in Engineering Mathematics I are mapped to the tested cognitive levels. Here, knowledge, understanding and application have become useful cognitive levels in planning suitable examination questions and will be used in these 2 models.

### 2.1. Model A.

The key decision for this model is to determine which subtopic should be tested so that satisfying the requirement of BT. The objective of model A is the model is using binary linear programming to choose the required subtopic that to be mapped with particular cognitive level. The allocation marks and also the constraint for each sub topics are shown in the Table 1. The objective function (1) is to maximize the allocation marks for application cognitive level.

Equations (2) represent the total allocation marks for each cognitive level, knowledge ( $z_1$ ), understanding ( $z_2$ ) and application ( $z_3$ ). Equation (3) is in binary form to ensure that each question must have one level of cognitive only. Meanwhile, equation (4) represent the total marks for all sub-questions must be 100. Constraints (5), (6) and (7) are referred as level of cognition constraint that required by question makers. The allocation marks for knowledge, understanding and application level of cognition must be greater than or equal 10%, greater than or equal 20%, greater than or equal 60%, of the total marks, respectively. Constraint (8) assures that the allocation marks for understanding cognitive level must be more than knowledge level. Constraint (9) is to ensure that the outputs of variable  $x_{ij}$  are integer.

Table 1. Model A

			Main Variable	Allocation Percentage	Knowledge	Understanding	Application
Main Variable					$z_1$	$z_2$	$z_3$
Allocation Percentage					$z_1 \leq 10\%$	$z_2 \leq 20\%$	$z_3 \geq 60\%$
1	Complex Number	Q1	$x_1$	10	$x_{11}$	$x_{12}$	$x_{13}$
		Q2	$x_2$	10	$x_{21}$	$x_{22}$	$x_{23}$
2	Matrix	Q1	$x_3$	10	$x_{31}$	$x_{32}$	$x_{33}$
		Q2	$x_4$	10	$x_{41}$	$x_{42}$	$x_{43}$
3	Vector	Q1	$x_5$	8	$x_{51}$	$x_{52}$	$x_{53}$
		Q2	$x_6$	12	$x_{61}$	$x_{62}$	$x_{63}$
4	Differentiation and Integration	Q1	$x_7$	5	$x_{71}$	$x_{72}$	$x_{73}$
		Q2	$x_8$	15	$x_{81}$	$x_{82}$	$x_{83}$
5,6	Vector	Q1	$x_9$	10	$x_{91}$	$x_{92}$	$x_{93}$
	Differentiation and Integration	Q2	$x_{10}$	10	$x_{101}$	$x_{102}$	$x_{103}$

Model A can be written as follow:

Objective function

$$\text{Maximize } z_3 \quad (1)$$

Subject to

Main variables constraints

$$z_j = 10x_{1j} + 10x_{2j} + 10x_{3j} + 10x_{4j} + 8x_{5j} + 12x_{6j} + 5x_{7j} + 15x_{8j} + 10x_{9j} + 10x_{10j} \quad (j = 1, \dots, 3) \quad (2)$$

Subtopics constraints

$$\sum_{j=1}^3 x_{ij} = 1 \quad (i = 1, \dots, 10) \quad (3)$$

$$\sum_{i=1}^3 z_i = 100 \quad (i = 1, \dots, 10) \quad (4)$$

Level of cognition constraints

$$z_1 \geq \sum_{i=1}^3 z_i \quad (5)$$

$$z_2 \geq 0.2 \sum_{i=1}^3 z_i \quad (6)$$

$$z_3 \geq 0.6 \sum_{i=1}^3 z_i \quad (7)$$

Additional constraints

$$z_2 \geq z_1 \quad (8)$$

$$x_{ij} = \text{binary} \quad (i = 1, \dots, 10; j = 1, \dots, 3) \quad (9)$$

**Model B.** The key decision for this model is to determine the optimal marks for each question based on the complexity level and satisfying the requirement of BT.

The objective function (10) is to maximize the allocation marks for application cognitive level. The constraints for this model and the allocation marks for each question is given in Table 2.

Model B can be written as follow:

Objective function

$$\text{Maximize } \sum_{j=1}^3 x_{10j} \quad (10)$$

Subject to

Main variables constraints

$$z_j = 8x_{1j} + 12x_{2j} + 8x_{3j} + 12x_{4j} + 10x_{5j} + 10x_{6j} + 10x_{7j} + 10x_{8j} + 10x_{9j} + 10x_{10j} \quad (j = 1, \dots, 3) \quad (11)$$

Subtopics constraints

$$x_{11} + x_{31} \geq 10 \quad (12)$$

$$x_{52} + x_{72} + x_{63} + x_{83} + x_{93} \geq 20 \quad (13)$$

$$x_{23} + x_{43} \geq 40 \quad (14)$$

Level of cognition constraints

$$\sum_{i=1}^{10} x_{i1} \geq 0.1 \sum_{i=1}^{10} x_i \quad (15)$$

$$\sum_{i=1}^{10} x_{i2} \geq 0.2 \sum_{i=1}^{10} x_i \quad (16)$$

$$\sum_{i=1}^{10} x_{i3} \geq 0.6 \sum_{i=1}^{10} x_i \quad (17)$$

Additional constraints

$$z_3 \geq z_2 \quad (18)$$

$$x_{ij} = \text{integer} \quad (i = 1, \dots, 10; j = 1, \dots, 3) \quad (19)$$

Table 2. Model B

			Main Variable	Allocation Percentage	Knowledge	Understanding	Application
Main Variable					$z_1$	$z_2$	$z_3$
Allocation Percentage					$z_1 \leq 10\%$	$z_2 \leq 20\%$	$z_3 \geq 60\%$
1	Complex Number	1	$x_1$	8	$x_{11}$	$x_{12}$	$x_{13}$
		2	$x_2$	12	$x_{21}$	$x_{22}$	$x_{23}$
2	Matrix	1	$x_3$	8	$x_{31}$	$x_{32}$	$x_{33}$
		2	$x_4$	12	$x_{41}$	$x_{42}$	$x_{43}$
3	Vector	1	$x_5$	10	$x_{51}$	$x_{52}$	$x_{53}$
		2	$x_6$	10	$x_{61}$	$x_{62}$	$x_{63}$
4	Differentiation and Integration	1	$x_7$	10	$x_{71}$	$x_{72}$	$x_{73}$
		2	$x_8$	10	$x_{81}$	$x_{82}$	$x_{83}$
5,6	Vector	1	$x_9$	10	$x_{91}$	$x_{92}$	$x_{93}$
	Differentiation and Integration	2	$x_{10}$	10	$x_{101}$	$x_{102}$	$x_{103}$

### 3. Results

The results of the analysis on Model A and Model B are using LINGO 11.0 packages. The result of Model A and Model B are summarized in Table 3 and Table 4 respectively.

Table 3. Results of Model A

			Allocation Percentage	Knowledge	Understanding	Application
1	Complex Number	Q1	10	0	0	1
		Q2	10	0	1	0
2	Matrix	Q1	10	0	0	1
		Q2	10	0	0	1
3	Vector	Q1	8	0	0	1

		Q2	12	0	0	1
4	Differentiation and Integration	Q1	5	0	1	0
		Q2	15	1	0	0
5,6	Vector	Q1	10	0	0	1
	Differentiation and Integration	Q2	10	0	0	1

Table 4. Results of Model B

			Knowledge	Understanding	Application
1	Complex Number	Q1	8	0	0
		Q2	0	0	12
2	Matrix	Q1	8	0	0
		Q2	0	0	12
3	Vector	Q1	0	10	0
		Q2	0	0	10
4	Differentiation and Integration	Q1	0	10	0
		Q2	0	0	10
5,6	Vector	Q1	0	0	10
	Differentiation and Integration	Q2	0	0	10

From the analysis results of the table 3 and 4, it can be concluded that the classification of examination marks for Model A and Model B have satisfied the both requirements of the percentage marks and BT cognition levels which have been decided by the question makers.

#### 4. Summary

In order to obtain optimal results for Model A and B, LINGO 11.0 package was used to compute the programming of all models. Clearly, the method of classification of examination marks on that models which is requirements of percentage have been decided by the question makers according to Bloom's taxonomy cognitive level.

Lecturers should consider Bloom's taxonomy while preparing question because by this way students can be tested with different types of question according to Bloom's taxonomy cognitive levels. These models also can be used by other courses by adjusting the parameters, variables and constraints to get the optimal distribution of question marks while preparing the examination questions. By comparing previous used method, the lecturer used to allocate the question marks manually, these models may assist the lecturers to allocate the questions marks correctly, reliable and available to be used for any courses without consuming much time.

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