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How to Construct Open Ended Questions

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Abstract

All institutions offering engineering programs are faced with significant challenges, especially in preparing students so that they can receive information, learn the technology, the principles and practice of engineering as well as adapting to the rapidly changing needs to compete globally. Criteria and targets set by the Engineering Accreditation Council (EAC) and the Malaysian Qualifications Agency (MQA) stipulate that these students must be able to process the information actively and critically, evaluate them in order to achieve the high level of professional skills. Apart from the use of teaching and learning strategies, assessment methods, such as open-ended questions from the higher level of Bloom's taxonomy can be used to develop the necessary professional skills. This study aims to examine and provide examples, the form and level of open-ended questions in the field of electrical engineering that can test the mind, and encourage students to think analytically, critically and outside the box. This paper discusses the analysis performed on four questions from the final exam in the second semester 2010/2011 session to measure qualitatively the open-ended questions posed by the lecturer and whether they complied with the features as described. Out of those four questions, one completely complied with the set feature, two out of four parts in another question complied while one question has not complied at all. Some suggestions are given to improve the level of a given question.

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1. Introduction

Each engineering program offered by the institution in Malaysia emphasized that the program outcomes should be achieved by the students to meet the criteria set by the Engineering Accreditation Council (EAC) and the Malaysian Qualifications Agency (MQA) as described in the manual EAC2011. It is the responsibility of all lecturers to ensure that all the graduates attain the professional skills set in 9 programs outcomes, such as the ability to formulate and solve engineering problems, design and evaluate operational performance to meet the economic constraints, environmental, social and political, to run the experiment and analyze data, communicate effectively, work in groups and others. All of these skills should be integrated into the curriculum and applied in core courses.

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In fulfilling the criteria set by the EAC and the MQA, each program should also be assessed by a competent international academics and experts in the formulation of related engineering curriculum. Appointed external assessors will evaluate in detail the curriculum offered, the level of examination questions, laboratory experiments and activities, final year projects and the qualifications of the lecturers. One of the issues that was raised in their evaluation report was on the manner the final examinations questions are formulated. In this case, the questions, especially at the university level, should be at a level of difficulty that can test students' critical and analytical thinking skills so that they could respond with extensive arguments to support their views and lead to the ability to make decisions. It also should be able to stimulate student creativity and help students to think deeply about the material covered in the lectures. These are the characteristics of an open-ended question that differ from closed-ended questions which are more focused on the demand for deterministic answers or one right answer.

As closed-ended question requires only one correct answer, students are more likely to memorize the statement or formula without deep understanding of the concept and content of a course being taught. In addition, these questions are more similar to the questions that were asked in the textbook.

This study was motivated by the lecturer's request to define open-ended questions, how to formulate these questions and how many percentage of this type of questions should be asked in the final examinations.

2. Literature Review

Open-ended question is not the form of a question that demands one correct answer. It is also not a question that can accept any answer. In contrast, open-ended questions address key concepts, processes and skills that go beyond specific instructions that define the critical content. In general, open-ended questions require complex thinking and produce a variety of solutions (Badger 1992). In electrical and electronic engineering, problem solving skills via open-ended question lead to an exploration in greater depth on the concept of electrical, interpret results and use of electrical techniques in the real world which is ambiguous and variable.

There are several benefits that can be obtained from the construction of open-ended question, one of which helps students to build confidence by solving problems in a natural way. Cooney et al. (2004) suggested that all students learn in different ways, and how they demonstrate their knowledge varies. Features or characteristics of an open-ended question allow students to find an approach to problem solving according to their choice. Therefore, the students' level of confidence is raised due to the increased challenges when answering open-ended questions. For example, Cooney et al. added that the students feel more confident when they need to make effort to solve problems which were unclear in the beginning.

Researchers of open-ended question stated that it is an efficient method of evaluation. Questions of this type can provide information about the students' achievement more clearly than multiple-choice questions or questions with deterministic answer and give better guidance to improve teaching. Badger (1992) states that by reading answers to open-ended questions, he could obtain more comprehensible information about the level of the students' reasoning ability and their achievement and also the quality of his teaching.

The main benefit of open-ended questions is to encourage deeper learning. Some believe that these types of questions could promote learning the concept, however, unlike procedural knowledge, it is easy to use in the unknown context outside the classroom. But, what is the level of challenge that could foster profound learning? Finkel (2000) states specifically that open-ended question should be like the parable of the puzzle that intrigue the mind, but also challenging enough so that students would be interested in the answer.

2.1. The Features of Open-ended Questions

Open-ended questions should be able to challenge the engineering students to demonstrate a deep understanding of the materials being studied, the ability to use techniques from other disciplines, and the ability to assess the value of design, product, or system (Felder 1987). Cooney et al (2004) stipulates that the open-ended question should include the following features:

1. It involves a significant concept in a related field. The assessment items conveyed to the students what needs to be emphasized and what is important. It could also have a number of objectives, thus giving students the chance to display their understanding by linking the entire topic and how it can lead to real-world problem solving.

2. There could be multiple answers to open-ended questions. When a question requires one correct answer, students often conclude there is only one way to solve the problem. Questions that require students to explain their thinking will encourage a variety of responses or reactions because not all students think the same. For example, can an equilateral triangle have right angle? If yes, explain your reasons. Typically, students focused on the angle and concluded that it is not possible, because all the sides of an equilateral triangle must have the same length and an equilateral triangle cannot have 270 degrees. But one student replied that no, because if it has a right angle it will have a hypotenuse. And it will become the longest side. But since all sides are of the same length so it cannot happen
3. Need to communicate the reasoning process. One strong point of using open-ended questions is that students are given the opportunity to communicate what is in their minds. If you look to this question, Mary claimed that the area of any 30-60-90 triangle can be calculated even if only one side of the given length. Is Mary right or wrong? Explain your answer. Here is an answer given by students: Mary is right. If you know the length of one side, you can divide or multiply with $\sqrt{3}$ or 2. After that, the height is multiplied with the base, divide by 2, and you will get the answer. Another student gave the following response: Mary is wrong. Since all the angles are different, then all the sides are of different length. By knowing only one side initially, you would need to know the length of the other two sides (height and base) to calculate the area of the triangle. The first student sees the relevance relations among the sides of the triangle 30-60-90, while the second student who may not realize this, does not see the relevance context of this problem. When students are required to communicate their reasoning process, it was easy to understand what they know and they can use this to solve the given problem.
4. Open-ended questions should be clearly stated. The fact is that open-ended questions should not be incomprehensible. These types of questions should have a clear purpose even if there are many different answers. In addition, students need to know what is expected of them and what lecturers consider as a good and complete response. Many lecturers find that sharing a variety of answers with their students and asked them to evaluate these responses helped the students to determine what constitutes a good response. This is because students are often not used to explain their thoughts in writing and it is important to help them to improve their communication, analytical and critical thinking skills.
5. Have a scoring rubric. Each item evaluated must have at least a 2-point rubric: yes or no. But the purpose of the open-ended questions is to provide students with the opportunity to communicate their understanding in something other than the scenario of exactly right or wrong answer. Therefore, the issue here is whether it is possible to think the answer has a value (better than the score 0) but is not eligible for full credit. To give students partial credit is a common perception, and using the rubric to formulate the process helps to ensure fairness. One of the features for a good open-ended question is to get the answer that agrees with the partial credit as defined by the rubric. As an example in the question of whether an equilateral triangle have a right angle? Answer yes or no does not involve a partial credit, but the answer to why will allow a partial credit to be given.

2.2. Challenges Faced In the Construction of Open-Ended Questions

Despite the fact that the open-ended questions are appropriate to evaluate and develop professional skills of students, sometimes they can also cause problems. Here are some of the situations that might arise from using open-ended questions:

1. Confuse the student. It is often risky that if the question is not properly constructed and administered, it will cause confusion. Wu (1994) documented three examples of very difficult questions which the students were unable to solve, or believe that no solution exists, for these problems require high level of thinking skills. He is concerned that students might conclude from open-ended questions that experimentation or conjecture can replace the analysis of arguments and evidence.
2. Provide a negative stimulus to the students. Apart from the wrong information, open-ended questions can undermine the spirit of the students in two stages: the time limit is required to formulate an answer and questions which could be vague and unclear.
3. Provide a negative stimulus to the lecturer. This involves increasing the workload to the lecturers for grading open-ended question which is strenuous and time consuming.

2.3. Construction of Open-Ended Questions

Students have their own ways to get to the right answer. Sometimes students can deceive a lecturer by showing that they understand the subject matter when in fact they do not. Lecturers need to formulate questions to discourage this deception. For example, when students see the picture as shown in Figure 1, they no longer need to struggle to read the question. They know that when all sides of the figure has a number, they should add the numbers if the question asks to calculate the perimeter of the figure shown.

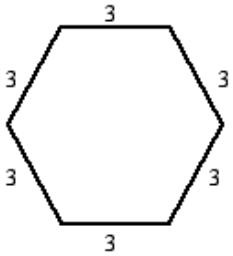


Figure 1. Example question

Does this question really allow the lecturers to assess whether a student knows anything about the perimeter? If the lecturer were to ask the students to sketch a six-sided figure with a perimeter of 18. Their answer to this question would give the lecturers more information about students' understanding of perimeter. Open-ended questions that ask students to generate examples that meet certain criteria allow the lecturers to distinguish the students' understanding of a topic.

Open-ended questions (Boaler 1998) can also be formulated from closed-ended questions, as shown in Table 1.

Table 1. Open-ended question as modified from the closed-ended question

Example of closed-ended questions	Modified to open-ended questions
Which of the following numbers are prime? 7, 57, 67, 117	*Fred thinks that 57 and 67 are prime because they both end in 7, which is a prime number. Dick says he is wrong. Who is correct and why?*
What are the next three numbers in the following sequence? 1, 4, 7, 10, 13, ___, ____, ____	*Consider the following sequence: 1, 4, 7, 10, 13, ... Is 100 a member of this sequence? Explain your reasoning.*
Round 37.67 to the nearest 10th.	*Generate three different numbers that when rounded to the nearest 10th give 37.7.*
Find the LCM of 18 and 24	*Why can't 48 be the LCM of 18 and 24?*

3. Results and Discussion

Analysis on the open-ended question has been performed on some sample questions from the final exam given to the students in EES (Electrical, Electronics and Systems) engineering department. Figure 2 a), b), c) and d) shows four sample questions extracted from the final examination of the courses offered in year 4 semester 2 2010/2011 session.

A project cash flow forecast is given in the table below. Decide whether this project is worth

undertaking by finding the Net Present Value and the profitability index of the project. Present value is given by the formula, PV=Future Value / $(1 + i)^n$, where I is the interest rate and n is the number of years. Present interest rate= 7 percent.

YEAR	*CASH FLOW(RM)*
0	*-850,000 (initial capital cost)*
1	*160,500*
2	*260,300*
3	*340,200*
4	*300,250*
5	*240,500*
6	*120,000*

(a) Question 1

a) Determine the optimum solutions at the end user level for improving overall voltage sag performance and reliability.

b) Design a simple test distribution system for the customer facility as shown in Figure 2. PCC-1 is the utility bus at 13.8 kV and PCC-2 is the customer bus at 480 V. The data of PCC-2 bus are as follows:

Tr_2 = 1000 kVA, 5.0% impedance on 1000 kVA base

I_{load} = 1000 A

The measured distortion is equal to 90 A at 5th harmonic and 44 A at 7th harmonic. The short circuit impedance on 13.8 kV bus is equal to 1.7% on 1000 kVA base.

(b) Question 2

a) Consider the traffic deadlock depicted in Figure 2.

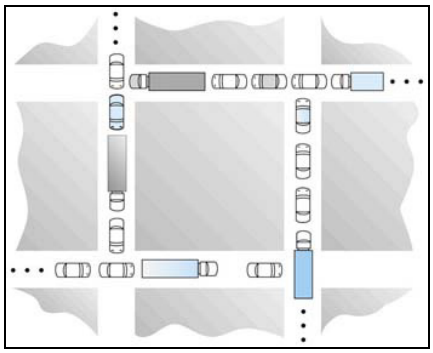


Figure 2 Traffic deadlock

a) Show that the four (4) necessary conditions for deadlock hold in this example.

b) Explain a simple rule for avoiding deadlocks in this system.

c) Is it possible to have a deadlock involving only a single process? Justify your answer.

d) Discuss the process of starvation and how aging can be used to prevent it.

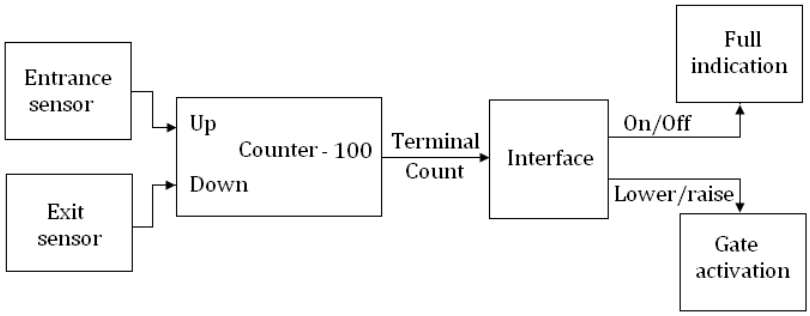
(c) Question 3

An up-down counter is used in an automobile parking control system. The system monitors the available

spaces in a one-hundred space parking garage and provide an indication for a full condition by illuminating a 'FULL' display sign and lowering a gate bar at the entrance. Optoelectronic sensors are used at the entrance and exit of the garage, an up/down counter and associated circuitry is used to count the number of parked cars and parking space available and an interface circuit that uses the counter to turn the 'FULL' sign on or off as required and lower or raise the gate bar at the entrance. The general block diagram is as shown in Figure 7. Unfortunately, one day, patrons complained that when they enter the garage (the gate was raised and the 'FULL' sign was off), and yet they can find no empty space.

a) As the technician in charge of this facility, Discuss with examples and illustrations, if any, what and where do you think the problem is.

b) Explain on the troubleshooting procedure and how will you troubleshoot and repair this system as quickly as possible



(d) Question 4

Figure 2. Examples of the open-ended questions

Table 2 shows the analysis performed to examine whether they are open-ended questions by investigating whether they meet the features as listed by Cooney et al (2004). The results obtained from the analysis showed that the question 1 does not fit feature 2 and 3, because it does not require multiple answers and the students do not have to display their reasoning process because this question does not require students to communicate the process. For question 2, part a) satisfies all the characteristics of an open question, but part b) does not fit feature 2 and 3 for the same reason as question 1. As for feature 5, *y* indicates no information available whether the scoring rubric is provided for the question. Question 4 shows that it meets all the feature of an open-ended question.

Table 2. Qualitative analysis of open-ended questions that met the feature

Question	Feature 1	Feature 2	Feature 3	Feature 4	Feature 5
1	√	x	x	√	y
2	√	Part a) √	Part a) √	√	y
		Part b) x	Part b) x	√	y
3	√	Part a) x	Part a) x	√	y
		Part b) √	Part b) √	√	y
		Part c) √	Part c) √	√	y
		Part d) x	Part d) x	√	y
4	√	Part a) √	Part a) √	√	√
		Part b) √	Part b) √	√	√

If the results obtained were examined, it appears that the important features of open-ended question that needed to be fulfilled are 2 and 3. Feature 5 will indirectly become necessary to facilitate the scoring to ensure fairness.

Based on the discussions, examples and the analysis performed, the confusion on the construction of open-ended question have been cleared and the lecturer could formulate questions that not only could test the students'

academic ability, but may also obtain feedback that can be used to improve teaching and learning process and produce students with professional skills. However, no study has been carried out on the percentage of open-ended questions that should be asked in the final examinations. It was simply stated that an open-ended question could be asked during the quiz, laboratory activities, projects and assignments. As such, the author finds that the open-ended question with 10 to 20 points in the final examination is sufficient to efficiently identify students who can think critically. But it needs further study as no other similar research work has discussed this.

4. Conclusions

In conclusion, the qualitative analysis of the study found that some of the questions asked by the lecturer are not completely open-ended question if it does not fit the features 2 and 3. With the examples given, it is hoped that a lecturer could construct excellent open-ended questions. Since open-ended questions can obtain feedback on students' understanding and their ways of thinking, generate critical and analytical thinking skill, it should be widely and generously used in quizzes, assignments, projects, etc., so that lecturers can improve strategies and processes of teaching and learning. Besides, it was also recommended that the open-ended questions posed in the final examination should consist of 10 to 20% of the total marks.

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References

Badger, E., B. Thomas, (1992). Open-ended questions in reading. *Practical Assessment, Res. and Evaluation,* 3(4).

Boaler, J. (1998). Open and Closed Mathematics: Student Experiences and Understandings. *J. for Res. in Math. Ed.,* 29(1), 41-62.

Cooney, T.J., W.B. Sanchez, K. Leatham, & D.S. Mewborn. (2004). Open-Ended Assessment in Math: A Searchable Collection of 450+ Questions. *Heinemann. Quotations taken from online version, books.heinemann.com/math*.

Felder, R. M. (1987). On Creating Creative Engineers. *Engineering Education*, 77(4), 222-227.

Finkel, D.L., (2000). *Teaching with Your Mouth Shut*. Boynton/Cook Publishers.

Wu, H., (1994). The role of open-ended problems in mathematics education. *J. of Math. Behavior,* 13(1), 115-128