Review Article

Best Practices in Designing Extended Matching Questions for Evaluating Higher Order Cognitive Skills in Medical Education

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ABSTRACT

Applying best practices in designing extended matching questions (EMQs) is fundamental for accurately assessing the higher order cognitive skills of medical students. EMQs, when well-constructed, can evaluate critical thinking, clinical reasoning, and decision-making skills, which are vital in the medical field. Prioritizing clarity, relevance, and complexity in question design, educators can create assessments that align more closely with real-world medical problem-solving. Implementing these strategies is a key step towards uplifting the standards of medical education. This paper offers a comprehensive guide in designing high quality EMQs that test higher order cognitive skills of medical students, aiming to promote best assessment practices in medical education and uphold high standards of student evaluation.

Keywords

Student assessment, Design, EMQ, Evaluate, cognitive skills, Medical education.

INTRODUCTION

Medical curricula are planned with precise content to ensure high quality medical education in order to produce competent medical doctors with the intention of providing high quality medical care to the communities and clients globaly[1]. Assessment is an important step in medical education that validates teaching objectives while benefiting both students and educators[2]. Assessment drives learning, and learning drives practice[3-7]. There are three main educational domains: cognitive (thinking), affective (feeling), and psychomotor (doing). In medical education, different assessment tools are employed based on the specific domains being evaluated. For example, the cognitive domain is tested using written formats such as multiple-choice questions (MCQs), essays and oral examinations, and the psychomotor domain is tested using OSPE/ OSCE or direct observation[8].

Among the different tools, MCQs are the most frequently used tools in written assessment. However, many in-house MCQs are found to be faulty in assessing knowledge in isolated

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facts and assessing lower levels of thinking skills[9]. It is difficult to assess clinical reasoning using this tool as it involves a doctor applying knowledge and experience to diagnose and manage a patient's problem[8,10]. A good assessment is a test that uses the tools to assess the higher order cognitive or thinking skills of the students[3]. Extended matching questions (EMQ) represents a variant of MCQ now used in medical education, which has proved to be able to assess higher-order thinking skills like clinical reasoning such as evaluating and creating[8]. This paper describes EMQs and outlines the process of designing high quality EMQs that test higher order cognitive skills of medical students, with the ultimate aim of promoting best assessment practices in medical education and uphold high standards of student evaluation.

EXTENDED MATCHING QUESTIONS (EMQ)

The EMQ was introduced in 1990 by Case and Swanson as a different MCQ format to be used in the United States Medical Licensing Examination (USMLE)[11]. In EMQs, the problem is presented as a short case called 'vignettes'. For example, a case is presented in a few sentences outlining the patient's symptoms and lab results, and the student is required to reach a diagnosis. They need to choose from a long list of choices rather than the traditional five choices used in the MCQ of single best answer (SBA) or one best answer (OBA) type[11,12]. The EMQ is a form of MCQ, organised into sets that use (1) a theme; (2) an extended option list varies from six to 25 or more potential answers; (3) a lead-in statement that directs the students or instructs what to do; and (4) at least two, or more patient-based vignettes or item stems related to theme requiring the student to specify a clinical decision for each item stem[10,11].

Theme

The theme is a topic or title of the EMQ set addressed by the set of item stems. Based on the theme, the EMQs examined all the disorders under the selected theme[11,13]. Themes can be related to basic science, such as anatomic sites, cell types, functions, pathogens, pathophysiological states, etc. It can be clinical signs or a symptom or chief complaint, for example, back pain, chest pain, dyspnoea, fatigue, etc.; a class of drugs like antibiotics, corticosteroids etc., investigation, laboratory data, diagnosis or treatment; and so on[9,14].

Options

Candidates are given an extended number of answer choices called options. The list of answer options varies from six to 25 or more choices or potential answer options including the correct answer [8,10,11,15]. The options are presented as single words or short phrases and arranged either alphabetically or numerically as appropriate. The options should be homogeneous, for example, all anatomical sites, all diagnoses, all therapies, etc. Students need to select one option for each numbered problem /case that most closely answers to the question[11].

Lead-in Statement

The lead-in is a question or statement that directs or instructs the students about their task or what they need to do. In most circumstances, it is preferred to ask in one of the best-answer response formats. The lead statements may be written as: 'For each patient described below, choose the single most likely management plan from the above list of options'; 'For each of the following patients, select the single most likely diagnosis or most appropriate investigation or most accurate figure', etc.[10]. However, lead-in can be structured to require the examinee to select more than one response, such as, 'For each patient with fatigue described below, select three laboratory studies'. There is a single lead-in statement used for all items in a set[14].

Item-stem

The item stems comprise the questions to be answered by students. It is a list of numbered clinical vignettes, which should be at least two and describe patients in clinical situations related to the theme. The vignettes can be described briefly or elaborated depending on the clinical scenario[10,11]. Usually, it is described in 2-6 sentences, for example, describing the patient's symptoms, the laboratory test results, etc. and the student is instructed to conclude a diagnosis to be chosen from several options rather than only 4-5 five options as in SBA/OBA. By understanding the information provided in the vignette, students come to a conclusion and answer by choosing from the list[12]. Vignettes containing relevant information are a crucial part of EMQ, as they enable students to effectively respond to the questions. Consequently, careful consideration should be paid to constructing EMQs with good patient vignettes[16].-

Stems within a set or the descriptions of the patients should be similar in structure in all the sets. For

illustration, if ethnicity or occupation is included in one item, it should be included in all items; if laboratory data are included in one item, include them in all items. It is advisable not to mix adult and paediatric cases in the same set as age is an important indicator for selecting or eliminating options[17].

TYPES OF EMQ

The EMQs are mainly of two types: R-type and N-type. In the R-type format, students are instructed to identify a single answer from the option list while in the N-type format, students are instructed to identify 2, 3, 4 or even 5 answers from the options list[11,13]. The rationale for decision to specify exactly how many options (2, 3, 4 or 5) to identify is derived from the main difference between multiple true/false and one-best-answer type of questions, where true/false items require the examinee to indicate all responses that are appropriate, and one-best-answer items require the examinee to indicate a specific number of responses[11]. The N-type EMQs are suitable in questions having a variety of possibilities or the answer is not clear-cut such as differential diagnosis, drug side effects, etc.[13]. Identifying the sspecific number of options changes the task from a multiple true/false task to a best-answer task[11]. -

The following are a few (six) examples of R-type (five) and N-type (one) of EMQs, three for basic science /pre-clinical phase and three for clinical phase, taken from Case and Swanson 1993 and 2001[11,17].

R-TYPE EMQ

EMQ 1.

Theme: Arterial involvement (Anatomy)[17]

Options:

A. Left anterior cerebral artery.
B. Right anterior cerebral artery
C. Left middle cerebral artery
D. Right middle cerebral artery
E. Left posterior cerebral artery
F. Right posterior cerebral artery
G. Left lenticulostriate
H. Right lenticulostriate arteries

Lead-in:

For each patient below with neurologic abnormalities, select the artery that is most likely to be involved. Each option can be used once, more than once or not at all

Stems:

1. A 72-year-old right-handed man has weakness and hyperreflexia of the right lower limb, an extensor plantar response on the right, normal strength of the right arm, and normal facial movements. **Ans: A**

2. A 68-year-old right-handed man has right spastic hemiparesis, an extensor plantar response on the right, and paralysis of the lower two-thirds of his face on the right. His speech is fluent, and he has normal comprehension of verbal and written commands. **Ans: G**

EMQ 2.

Theme: Arterial blood gas (Physiology)[11,17]

Options	pH	PO_2 (mmHg)	PCO_2 (mmHg)	HCO_3 (mEq/L)
A.	7.15	98	33	11
B.	7.15	98	24	8
C.	7.30	56	80	38
D.	7.40	100	40	25
E.	7.50	100	33	25
F.	7.50	100	24	18
G.	7.50	56	33	25

Lead-in:

For each patient described below, select the most likely arterial blood gas findings. Each option can be used once, more than once or not at all.

Stems:

1. A 22-year-old man with a 3-week history of polyuria and polydipsia has had nausea, vomiting, and decreased responsiveness for the past 12 hours. Urinalysis (dipstick) shows 4+ glucose and 4+ ketones. **Ans: B**
2. A 25-year-old woman is brought to the emergency department 12 hours after a suicide attempt. She took approximately 100 500-mg aspirin tablets. **Ans: F**

EMQ 3.

Theme: Adverse effect of drug (Pharmacology) [17]

Options:

A. Acetaminophen
B. Amiodarone
C. ACE inhibitors
D. Aspirin
E. Atenolol
F. Bleomycin
G. Cytosine arabinoside
H. Furosemide
I. Metronidazole
J. Nalidixic acid
K. Nitrofurantoin
L. Penicillin
M. Prednisone
N. Procainamide
O. Propranolol
P. Sulfasalazine
Q. Tetracycline
R. Verapamil

Lead-in:

For each patient, select the drug most likely to have caused the adverse effect. Each option can be used once, more than once or not at all.

Stems:

1. A 56-year-old man with recurrent ventricular arrhythmias began taking an antiarrhythmic drug 5 months ago. He now has progressive dyspnoea, cough, and low-grade fever. Erythrocyte sedimentation rate is increased. X-ray film of the chest shows a diffuse interstitial pneumonia. Pulmonary function tests show that diffusing capacity for carbon monoxide is decreased.
Ans: B

2. A 62-year-old man with chronic obstructive pulmonary disease begins therapy with an antihypertensive drug. Two weeks later, he has marked worsening of dyspnoea and clearly audible wheezing. **Ans: O**

EMQ 4.

Theme: Back pain (Clinical)[1]

Options:
A. Ankylosing spondylitis
B. Aortic dissection
C. Intervertebral disc infection
D. Lumbar spondylosis
E. Metastatic malignancy
F. Pars interarticularis defect
G. Prolapsed intervertebral disc
H. Vertebral fracture

Lead-in:
For each patient with back pain, select the most likely diagnosis. Each option can be used once, more than once or not at all

Stems:
1. A 23-year-old man has a 6-month history of lower back pain. His pain is predominantly at the thoracolumbar junction and in the right buttock. The pain is worse in the morning and he has difficulty in getting out of bed. There is some improvement during the day. Examination shows restriction of lumbar spinal movements, particularly lateral flexion. **Answer: A**

2. A 32-year-old lady presents with acute onset of low back pain. The pain is constant and is not significantly affected by posture. All spinal movements are painful and difficult. Three weeks earlier, she had a urinary tract infection which had been treated with amoxicillin. **Answer: F**

STEPS IN WRITING EMQ

The steps for writing EMQ are as follows[9,11,18]

(1) First, identify the 'theme' for the EMQ set. The theme is a topic or a title for a set addressed by the set of matters. It can be chief complaints (e.g. chest pain, fatigue), a drug class (antibiotics), or basic science themes such as anatomical sites, cell components, pathophysiological states, pathogens, etc.

(2) Prepare the list of relevant and realistic 'options'. A comprehensive options list includes all relevant options, rather than requiring students to guess the three or four distractors they think will be most appealing[11]. Depending on the nature of the options and the emphasis on the basic science versus clinical sciences, the vignettes are short and focused in some cases and long in some cases[11]. The EMQ format aids in specifying and organising exam content. Here, the options list flows from the theme, lead-in, and stem flows from the option list[11]. The options list should be in single words or very short phrases and homogeneous, for example, all diagnoses, all management, all anatomical sites, all vitamin options, etc.). The options, especially those involving laboratory values, are often expressed in tabular form. Eight to ten options are usually used, followed by at least two or more patient-based scenarios requiring the examinee to indicate a clinical decision for each item[9,18].

(3) Write the 'lead-in'. Example; 'For each of the following patients, select the most likely diagnosis'. Lead-in designates the relationship between the stems and options, clarifying the question for examinees.

(4) Write the 'item stems'. Item stems are the patient vignettes or clinical scenarios. There should be a minimum of two vignettes, while three vignettes with 8-10 options are preferable. The length of the stem or vignettes affects reading time, as longer vignettes take more time to read than shorter ones. The EMQ set that test the application of knowledge require more time than those test recall of isolated facts.

(5) Review the items for 'quality control'. After complete preparation of the EMQ, the written question, especially the stem /patient vignettes /clinical scenario, needs to be checked to make sure that there is a 'single best' answer for each question. Also to be confirm that at least four realistic distractors are present for each question. Then, for the final check, ask the help from one or more colleagues to review the items without

EMQ 5.

Theme: Fatigue (Clinical)[11,17]

Options:

A. Acute leukemia
B. Anemia of chronic disease
C. Congestive heart failure
D. Depression
E. Epstein-Barr virus infection
F. Folate deficiency
G. G6-phosphate dehydrogenase deficiency
H. Hereditary spherocytosis
I. Hypothyroidism
J. Iron deficiency
K. Lyme disease
L. Microangiopathic hemolytic anemia
M. Miliary tuberculosis
N. Vitamin B12 (cyanocobalamin) deficiency

Lead-in:

For each patient with fatigue, select the most likely diagnosis

Stems:

1. A 19-year-old woman has had fatigue, fever, and sore throat for the past week. She has a temperature of 38.3 C (101 F), cervical lymphadenopathy, and splenomegaly. Initial laboratory studies show a leukocyte count of 5000/mm3 (80% lymphocytes, with many lymphocytes exhibiting atypical features). Serum aspartate aminotransferase (AST, GOT) activity is 200 U/L. Serum bilirubin concentration and serum alkaline phosphatase activity are within normal limits. **Ans: E**

2. A 15-year-old girl has a two-week history of fatigue and back pain. She has widespread bruising, pallor, and tenderness over the vertebrae and both femurs. Complete blood count shows hemoglobin concentration of 7.0 g/dL, leukocyte count of 2000/mm3, and platelet count of 15,000/mm3. **Ans: A**

N-TYPE EMQ

EMQ 6.

Theme: Diagnostic Testing (Clinical)[17].

Options:

A. Analysis and culture of cerebrospinal fluid
B. Blood culture
C. Complete blood count
D. Examination of the stool for leukocytes
E. Measurement of serum electrolyte levels
F. Urinalysis
G. Urine culture
H. X-ray film of the abdomen
I. X-ray film of the chest

Lead-in:

For each child with fever, select the appropriate initial diagnostic studies.

Stems:

1. A previously healthy 1-year-old girl is brought to the emergency department because of fever for 1 day. Her temperature is 41 C (105.8 F). She is otherwise asymptomatic. Physical examination shows no abnormalities. (SELECT 4 STUDIES). **Ans: B, C, G, I**

2. A 7-year-old boy with sickle cell disease is brought to the emergency department because of fever for 1 day and chest pain for 1 hour. His temperature is 39.5 C (103.1 F). Breath sounds are slightly decreased in the right lower lung; he is not in respiratory distress. (SELECT 3 STUDIES). **Ans: B, C, I**

the correct answers indicated. If it is difficult for the colleague to determine the correct answer, then the option list or item needs to be modified to eliminate the ambiguity.

(6) Time allocation: One minute per stem /vignette appears to be sufficient generally for some sets of EMQ. In contrast, less than 20-40 seconds may be appropriate for others depending on the attitudes toward "speededness"[11]. This is a rough guideline for timing, and more research is needed. Faculty also need to determine the time allocation based on the characteristics of vignettes in consensus.

THE ROLE AND BENEFITS OF EMQ IN MEDICAL EDUCATION

The EMQs are now increasingly practising in medical education for undergraduate and postgraduate courses[10]. The assessment of clinical reasoning is appropriate with EMQs as the question is constructed as a clinical scenario with relevant questions. Moreover, having several options reduces the guessing of the correct answer[10]. The EMQs are reliable assessment tools to test the core knowledge and clinical reasoning of students[15], and are feasible, reliable, valid, authentic, and able to discriminate good from poor performers[19]. The EMQs can be stored in the question bank, modified and recycled, and used repeatedly[13]. They can be electronically scored; results can be statistically analysed and problematic questions can be identified[13]. However, constructing a high quality EMQ presents challenges and can be time-consuming for the faculties.

Medical education, though constantly changing, traditional curricula, inadequate funding, lack of objectivity, varying standards of assessment methods with weak quality assurance in higher education are a big problem[4,20,21]. Underestimation of assessment blueprint and lack of formal training on question and blueprint construction are added to the problem[3]. An assessment blueprint is a plan or test specification table /template (TST) that fixes the learning outcomes with related content to be tested and lists the number of questions and type of questions across the content with relative weightage among three educational domains[22,23,24]. As teaching and assessment are regarded as two sides of the same coin[4,20], there needs to be a well constructive alignment between teaching and assessment. Teachers must understand the process of teaching-learning and procedures of assessment to ensure the reliability and validity of the assessment[25]. The 21st century is a rapid development of science and technology, which makes people continuously improve, to add knowledge and ability[7]. It is necessary to train the faculties to construct high quality EMQs that assess higher level of cognitive skills of the students[13].

Effective training is always an important factor for the competency of the staff to fill the gap between desired performance and actual staff performance[26]. Faculty members are the valuable scholarly assets within institutions, and faculty development is an integral part of an institution's educational advancement[27,28]. Hence, well-trained trainers should implement faculty developmental programmes regularly for a sustainable institutional development[3]. Faculty development serves as the foundation for any curriculum innovation; without it, curriculum improvements would be impossible[29]. Therefore, institutions should prioritize regular faculty development programmes led by well-trained facilitators to ensure sustainable growth and development through the effective use of high-quality EMQs.

CONCLUSION

This paper offers a comprehensive guide for medical educators worldwide on how to design high quality EMQs for best practices in the assessment of higher-order thinking skills of students. The EMQs are a variant of MCQs suitable for testing medical students' clinical reasoning and problem-solving skills. Here, the students resolve a problem rather than recall isolated pieces of information. Using the EMQ can greatly reduce technical flaws, where students are instructed to choose an option from several options rather than only from 4-5 options, as in SBA/OBA. There is less chance of examinees guessing the correct response because of more relevant options. By integrating a well-defined theme, an extended list of relevant options, a clear lead-in statement, and two or more item stems, educators can create assessments that truly reflect the cognitive capabilities of their students. It is essential for EMQs to align with the learning objectives of the medical curriculum to ensure that they accurately measure the competencies required for clinical practice. Additionally, EMQs should be integrated into a broader assessment strategy that includes diverse evaluation methods to comprehensively assess medical student's competencies.

Creating a high-quality EMQ is a challenging task, and well-trained, experienced examiners can construct it. Training among the faculties is necessary to construct a high-quality EMQ. Medical schools should consider the needs of the faculty while organising faculty developmental training workshops to forge links between education and practice to ensure sustainable development. By adhering to above mentioned best practices and recommendations, medical educators can significantly enhance the quality of assessments, thereby fostering a deeper understanding of medical knowledge and improving the readiness of future healthcare professionals.

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Authors' Contribution

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