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Practical examples of using different levels of Bloom's taxonomy on a sample of multiple choice questions chosen from biomechanics & Kinesiology exams

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Abstract : Multiple choice questions (MCQs) exams are considered the gold standard to assess the knowledge acquisition; however, there is escalating debate regarding the effectiveness of using MCQs to test higher levels of thinking like analysis, evaluation and synthesis. Academics need to have a percentage of questions that covers all levels and dimensions. In addition, using the action verbs belongs to every level according to new Bloom's taxonomy will help in designing robust exams. The objectives are to 1)clarify the difference between old and new Bloom's taxonomy to promote using higher level of thinking by academics; 2) clarify the limitations associated with using MCQs exams as classroom assessment techniques; and 3) share some practical examples of MCQs, with increasing cognitive complexity, used within the biomechanics and kinesiology course. The methodology emphasized on reviewing literature belongs to old and new Bloom's taxonomy in addition to the limitations inherited to using MCQs for testing academic achievements. Also, discussing number of questions that were already used within the biomechanics and kinesiology course taught at undergraduate programme. It can be concluded that practical examples of MCQs from biomechanics and kinesiology courses can be used as a framework for designing MCQs exams.

Keywords :Test blueprinting, critical thinking, reasoning, competence, content analysis.

Introduction

Multiple choice questions (MCQs)is the gold standard for knowledge acquisition therefore, it should be carefully constructed to reflect the genuine competence of learners. Poorly constructed MCQs not only would not indicate the actual performance and competence of learners but would also allow incompetent test takers to guess and pass.[1]Educationalists have criticized the ability of MCQs exams to test higher critical thinking skills despite being the gold standard.[2]Unfortunately, the academics in the field of rehabilitation particularly physical therapy, are lacking research studies and educational articles that primarily have been designed to educate them on different levels of cognitive processes dimension and knowledge dimension coupled with its practical application for a given physical therapy course. It has been hypothesized that novice and/or inexperienced academics, in the field of rehabilitation and physical therapy, have the fundamental skills to develop valid MCQs exams that can reliably test the higher critical thinking skills.

Materials and Methods

The method section will be discussed using three major sections. The first section will clarify the difference between old and new Bloom's taxonomy, the second section will clarify the limitations inherited to using MCQs as assessment technique, and the third section will discuss some practical examples of MCQs used within the biomechanics a kinesiology course. The MCQ will be presented on a continuum of increasing cognitive complexity from lower- to higher- order thinking skills. The biomechanics and kinesiology courses are taught by Dr. El-gohary who has extensive academic as well as clinical experience in the field of physical therapy and rehabilitation. Dr. El-goharyholds philosophy of doctorate degree, has 22 years of experience in the academic field, is a board certified specialist and holds the title of orthopedic clinical specialist, is certified in mechanical diagnosis and therapy from McKenzie institute of North America, is being certified ergonomic assessment specialist. Questions will be fully discussed to share experience with academics in the rehabilitation field. Ethical approval was obtained from college of medical rehabilitation, Taibah University (Approval # CMR-PT-2017-008).

Bloom's Taxonomy: Old and new Bloom's

Early 1956, Benjamin Bloom and other scholars published a conceptual framework for categorizing educational objectives that have been largely adopted by school teachers and academics.[3]The framework originally consisted of six major categories. The first category is the knowledge which is the precondition for putting skills into practice. Knowledge involves the recall of specifics and facts. The second category is comprehension which refers to interpretation and understanding what is being communicated. The third category is application which refers to demonstration of an understanding. The fourth category is analysis which refers to breakdown a whole and shows the relationship between elements. The fifth category is synthesis in which involves putting elements together to form a new whole. The sixth category is evaluation which refers to estimation of the value of certain methods for given purposes.[4-6]In 2001, a group of scholars and specialists published the revised version of Bloom's taxonomy which is a more dynamic classification that uses action verbs to describe the cognitive processes. The revised Bloom's had rearranged categories and used a separate taxonomy of the types of knowledge used in cognition.[7,8] Currently, the latter three or four levels of Bloom's taxonomy are placed in a similar hierarchy denoting that all need some sort of problem solving.

The knowledge spectrum ranges from factual knowledge, conceptual knowledge, and procedural knowledge to metacognitive knowledge. Factual knowledge involves knowledge of terminology and elements while conceptual knowledge involves knowledge of structures, theories, principles and classifications. Procedural knowledge involves knowledge of using appropriate procedure, subject-specific skills and techniques while metacognitive knowledge involves self-knowledge and strategic knowledge.[8] Academics have been using Bloom's taxonomy as a framework to organize and clarify objectives for students in order to design valid assessment tools that align with the course objectives and teaching strategies. Academics should work on promoting higher level of thinking that focus on analysis and evaluation skills rather than just remembering facts.[2,9,10] Academics facilitate learners' acquisition of a new skill, knowledge and/or attitude. The three domains of learning may be thought of as three categories.[6]The oversight of psychomotor domain is attributed to the lack of experience in teaching manual skills at the college level. Academics must make sure that learners have mastered simple category of cognitive domain before the next or most complex category can be achieved.[2,11]

Bloom's Taxonomy and MCQs limitations

Bloom's taxonomy describes students' understanding of concepts, demonstration of particular skills, and how values, attitudes and interests are affected. Bloom's taxonomy and the action verbs associated with its different levels or categories play a vital role in the goal-defining process. Therefore, it can identify the most appropriate classroom assessment techniques for measuring the set goals.[4]Multiple choice questions exams are the most common form of assessment techniques used by academics and health care providers.[11,12]It might be satisfactory for assessing knowledge and comprehension but it often falls short of expectation for assessing higher levels of thinking like evaluation and synthesis. In addition, MCQs exams might be quite adequate for providing information about achieving knowledge-based goals but rarely provide information regarding achievement of either skill-based or affective-based goals.[10-12] For example, it is short of describing the level of expertise belongs to skill-based goals like knowing the steps needed to complete an objective, perform a task or

create new task. Also, it is short of describing the level of expertise belongs to affective-based goals like demonstration of willingness to participate in activity, showing interest in the object and adopting a long term value system. The traditional course evaluations are short of providing adequate information regarding students' values, attitudes, and interests. Moreover, traditional assessment techniques do not provide satisfactory feedback regarding achievement of course goals. Therefore, academics must make sure that the curriculum or intended learning outcomes, instructional methods or teaching strategies, and classroom evaluation-assessment techniques are properly aligned with the course objectives and goals.

Practical examples of using MCQs within biomechanics and kinesiology course

For the purpose of discussion, all levels of Bloom's taxonomy will be fully discussed using practical MCQs samples. Questions will be answered and the rationale behind choosing certain answer while omitting the rest will be fully explained. The logic of writing the answer options will also be discussed. The scientific material will mainly focus on biomechanics and kinesiology since it is a core course in the majority of physical therapy programmes. The discussion of MCQs belongs to every category will be divided into 2 sections: question stem with its answer options and comments. All data were analyzed using SPSS version 22.

❖ **Knowledge Category**

Q_1: The best synovial ball and socket joint in the upper extremity is:

a) The proximal radioulnar joint
b) The radiocarpaljoint
c) The elbow joint
d) The shoulder joint

Comments:

The correct answer is (d) since the "a", "b" and "c" options belongs to pivot, ellipsoid and hinge classification respectively. The learner needs just to recall joint classification in order to pick the correct answer. The academics can ask learners about the description of articulating surfaces but under the comprehension category.

❖ **Comprehension Category**

Q_2: During gait analysis, recording spatial variables includes:

a) Step length, stride length, and foot angle
b) Stride length and ground reaction force
c) Step length, stride length, and cadence
d) Stride length, foot angle, and cadence

Comments:

The correct answer is (a) since its elements all belongs to spatial variables while "b" option has kinetic element which is the ground reaction force, option "c" and "d" both have temporal option which is cadence. When writing the answer options, academics must make sure that the contents are grammatically parallel and consistent with the stem. Academics must make sure to include questions that test higher thinking skills like analysis particularly when it is derived from common every day activities that clinicians are encountering.

❖ **Application Category**

Q_3: A 30-year old athlete is doing leg press exercises, generating a force of 20 Newtons at 5 rad/sec angular velocity, will generate a muscle power:

a) Equals 15 Newton. rad/sec
b) Equals 100 Newton. rad/sec
c) Equals 25 Newton. rad/sec
d) Equals 4 Newton. rad/sec

Comments:

The correct answer is (b) since power is the product of force x velocity. The answer options "a", "c" and "d" were omitted since they denoted subtraction, addition and division processes respectively. Academics must make sure that the test taker is choosing between different answers that have certain logic and not just random answers. Testing the learners' ability to calculate denote application of what they have learned under application category of the cognitive domain.

❖ **Analysis Category**

Q_4: During midstance to terminal stance phase of gait cycle, the ankle and foot demonstrate:

a) Open kinematic chain as the foot moves toward the tibia
b) Open kinematic chain as the tibia moves toward the foot
c) Closed kinematic chain as the foot moves toward the tibia
d) Closed kinematic chain as the tibia moves toward the foot

Comments:

The correct answer is (d) since the subphase of midstance to terminal stance denotes closed kinematic chain and gait analysis signifies movement of the tibia towards the foot. Answer options "a" and "b" were omitted since open kinematic chain denotes that foot left the ground while the subphase of midstance to terminal stance has the foot in contact with the ground. Answer option "c" was omitted since the gait analysis indicated movement of the tibia towards the foot however the answer indicated the opposite.

❖ **Evaluation Category**

Q_5: John is 17 years old student who has the diagnosis of post traumatic weakness of right hip abductors. Observational gait analysis showed a pathologic gait pattern which was judged by noticing that John tends to:

a) Lean over the right side during stance phase of gait cycle
b) Lean over the left side during stance phase of gait cycle
c) Lean over the right side during swing phase of gait cycle
d) Lean over the left side during swing phase of gait cycle

Comments:

The correct answer is (a) since the patient tends to lean towards the affected side during the stance phase in order to decrease the body weight moment arm which decreases the torque required by the weak muscles. The "b" option was omitted since leaning towards the opposite side will increase the body weight moment arm which in turn increases the demands on the weak muscles. Regarding options "c" and "d" they were omitted since they included leaning towards either side but during the swing phase of gait cycle. Answers were incorrect since the muscle torque is needed from the muscles of the stance limb. Academics must put questions that communicate the higher level of thinking especially that have clinical implications.

❖ **Synthesis Category**

Q_6: Adam is a novice athlete who just had knee surgery four days ago. The best approach, from safety perspective, to create a training volume for Adam is through using:

a) A 50 Kg weight with a 2 repetitions, for a period of three weeks.
b) A 20 Kg weight with good number of repetition for two weeks.
c) A 5 Kg weight with a 20 repetitions, two times/ day for 3 weeks.
d) A 10 Kg weight with 10 to 20 repetitions, two times/ day.

Comments:

The correct answer is (c) since novice athlete needs low intensity to begin with to ensure safety in addition to have the repetition, frequency and duration of training. Option "a" has high intensity and does not

have the frequency of the training volume. Option "b" has high intensity and is subjective regarding the number of repetition in addition to lacking the frequency of the training volume. Option "d" is less safe, has undetermined repetition and is missing the duration of training. Academics must teach the health care learners to create objective goals based on the best available evidence. It is known that novice athletes need low intensity with objective number of repetition, frequency and duration. A fully descriptive and specific therapeutic or functional goal will enable clinicians to objectively measure any progress during rehabilitation programme.

Discussion

Academics must take all necessary measures to make sure that questions and answer options are correct from scientific, educational, linguistic and formative perspectives. Short and long case scenarios are always encouraged to test learners' abilities throughout the cognitive domain with its six categories. Questions with its answer options should communicate the higher critical thinking skills of analysis, evaluation and synthesis without mainly focusing on knowledge and comprehension.[2] Critical thinking skills including clinical reasoning and clinical judgments must be integral part of the exams to develop learners' capabilities.[13-17] Academics should continuously develop their skills of formulating MCQs exams. Poorly written questions facilitate less capable learners' and test takers to guess the correct answer without having the necessary competence.[18-20] Academics should make sure that the narrative part of the MCQs is in the question stem. Academics could supplement MCQs with graphs and diagrams. Also, all of the above, none of the above, and double negatives must be avoided in addition to have answer options with the same length. Academics must make sure that grammar is pertinent throughout using all plausible distractors.

In the following paragraphs, a thorough discussion of the questions that covered all learning domains and its six categories will be analyzed and evaluated for its soundness. The blueprint created and published by Dr. el-gohary (Appendix I) is included and would serve as mirror to guide academics to develop their MCQs exams. In reference to question number one, the learner was asked to choose the synovial ball and socket joint in the upper extremity. The learner had to just identify the ball and socket joint from a list of upper extremity joints. The verb identify is just to retrieve relevant knowledge from long-term memory but it needs strategies for retaining this abstract knowledge. Learners supposed to have appropriate contextual and conditional knowledgeto answer such a question. Regarding question number two, the verb recording needs learners to understand what is meant by spatial variables using the cognitive process dimension and to classify and clarify what elements belong to spatial variables using the knowledge dimension. Learners' abilities to classify and clarify spatial variables belong to the conceptual and procedural subtypes of knowledge dimension. In reference to question number three the learner should be able to calculate the muscle power. Calculation is one of the verbs used to test the application level when using MCQs exam but academics have a better chance to test learners' application abilities in the subjects that have practical or clinical components. Regarding question number four, learners should have keen power of observation and good analytical skills. Learners must be able to visualize the kinematics of observational gait analysis and break down the gait cycle into its subphases using the cognitive process dimension. Learners should also be able to differentiate open and closed kinematic chain using the knowledge dimension. Analysis skills are essential to enable clinicians to move to the next step of judging the situation based on the findings within the framework of the accepted criteria and standards.[21]

Scenario based MCQs are more likely to mimic the clinical cases that clinicians are encountering every day.[22]For example question number five was a short scenario based multiple choice question that included the diagnosis and objective physical finding. The patient demonstrated pathologic gait pattern and the clinician had to evaluate the deviations from normal gait pattern using observational gait analysis. Gait analysis using observational skills is considered one of the basic competence and skills that every clinician should have to be capable of providing the proper management for rehabilitation patients. Regarding question number six, clinician should be able to create a training volume through integrating the intensity, repetition, frequency and duration based on the best available evidence. Clinicians supposed to write short and long term goals that align with the patient's rehabilitation potential. Academics can use the answer option that has multiple components to upgrade the answer from just simple recall or description to more complex synthesis answer option that require clinician to use clinical judgment skills that need integration of multiple components to choose the best answer.[15] Finally, academics must know that there is no clear distinction between different categories or dimensions even though there are hierarchical steps to represent the cognitive process and knowledge

dimensions.[23] The overlap of different levels of Bloom's taxonomy is accepted and gives academics the chance to formulate MCQs that are in the analysis -evaluation spectrum or the evaluation- synthesis spectrum. The overlap is always in the consecutive levels of Bloom's taxonomy but it is unlikely to be in the knowledge-evaluation spectrum since there are too many levels on the cognitive process dimension that lie between knowledge and evaluation. Statistical analysis of MCQs exams using difficulty index and discrimination index showed that students are always having difficulties with calculation, analysis and evaluation but they are more likely to correctly answer questions that require the lower cognitive levels of recalling and describing certain knowledge.[24]Taib and Yusoff[25]encouraged academics to use MCQs exams for assessment of medical students since it has good psychometric properties, difficulty and discrimination indices. Academics could add ambiguity or irrelevant information to match real life circumstances to upgrade the difficulty of the questions.

Conclusions

Academics should continuously work on building students' skills to achieve learning objectives through gradual buildup of knowledge acquisition according to the hierarchy of Bloom's Taxonomy.

Appendix I
Subject's Name& No:

		Acquisition of knowledge as hierarchy of Bloom's Taxonomy						
		Knowledge Recall % Identify-Label	**Comprehension Interpret %** Describe- Explain	**Application Demonstrate %** Calculate- illustrate	**Analysis Formulate %** Discuss- Solve	**Evaluation Appraise %** Judge- Estimate	**Synthesis Integrate %** Create-Write	
		( )	( )	( )	( )	( )	( )	
								Sum
( )	**Topic 1**							
( )	**Topic 2**							
( )	**Topic 3**							
( )	**Topic 4**							
( )	**Topic 5**							
( )	**Topic 6**							
( )	**Topic 7**							
( )	**Topic 8**							
( )	**Topic 9**							
( )	**Topic 10**							
( )	**Topic 11**							
( )	**Topic 12**							
( )	**Topic 13**							
( )	**Topic 14**							
( )	**Topic 15**							
Total ( )		**Sum=**	**Sum=**	**Sum=**	**Sum=**	**Sum=**	**Sum=**	**Total=**

Q_n; Question number

Instructions: Start by filling up the parentheses with the number of question that correspond to the percentage required by 1) different levels of Bloom's taxonomy; 2) the topics weight as a % of total course time; 3) the intended learning outcomes. See the next equations.
(Total number of exam questions) X (% of topic weight) and/or (Total number of exam questions) X (% of Bloom's taxonomy)
N.B. MCQ, case scenario MCQ*, and short essay** are encouraged. Have the subject and the program intended learning outcome available before you.

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Authors' contributions

The author conceived and designed the study, collected and analyzed the data, drafted the manuscript, reviewed and approved the final draft, and submitted the initial manuscript.

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