

# An update of multiple choice questions (MCQs): the sequential multiple choice questions (SMCQs)†

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## Abstract

This report describes the process of developing a new type of multiple-choice question (MCQ), called sequential multiple-choice questions (SMCQs), in order to reduce the probability of answering correctly by chance and contrast the students' tendency to copy. In SMCQs the five possible answers to a question are connected to one another on an approximation scale towards the most probable answer.

**Keywords:** *pharmacy continuing education, professional education, skill evaluation*

## Introduction

Recently, the assessment of university students or participants in job competition examinations has been frequently carried out by using multiple-choice questions (MCQs). This type of test, used in Italy for many years in order to achieve a motor vehicle driving licence, has also increased in popularity for evaluation in other fields. Within universities, for instance, students are admitted upon a selection based on a MCQ test. At present, this type of test is being extended to many other exams in the university curriculum, where it is generally used for the preliminary selection of the candidate. Similar tests are also used for recruitment both in the private industry and in the public administration.

This kind of didactic evaluation has also been used at the Faculty of Pharmacy at the University of Bari. As a consequence, on the national and international market, people can find a large number of publications, both in paper and

electronic format, which allow potential candidates to practise the necessary skills to pass the exam (Romano & Wiener, 1983, Hall & Reiss, 2004, Azzopardi, 2004). In the USA, several question texts designed to assist candidates who are to take the National Association of Board of Pharmacy Examination (NABPLEX) and state pharmacy licensure examinations have been published.

Over the last ten years in Italy, the authorisation to run a pharmacy business is given on the condition that one possesses a degree in Pharmacy and passes an examination in which the candidate has correctly answered at least 75 out of 100 MCQs. Potential applicants are short-listed according to their score of the written test, which is added to the qualification scores assigned from work carried out in the field of Pharmacy, and to possible publications consistent with the application. The result of the application, which provides the finalist with the authorisation to own a public pharmacy, also leads to professional and economical

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recognition: therefore, the number of applicants is generally very high.

In order to guarantee the same conditions to all participants, the Italian State has developed a series of devices. A national Commission - of which one of the authors of this article was a member - developed 3000 MCQs. One hundred MCQs are selected from this bank of 3000, and drawn, resolved, and evaluated electronically in the presence of all candidates.

This method, which has been used for about 80% of the applications carried out in several Italian provinces during the last ten years, has not been the cause of any appeals regarding the way the test is carried out.

Although the institutive law on this kind of competition demands a biennial change of the 3000 questions, this rule has never been applied; the initial questions formulated are still in use. The non-execution of this rule of law is due to the objective difficulty to create, every two years, questions which are different from the previous ones, by means of heterogeneous and plethoric national commissions.

For some years the Faculty of Pharmacy in Bari has used some of the above-mentioned competitive examination questions as a screening test for admission to the oral examination of some disciplines.

For the first two years, the results obtained were satisfactory: candidates who passed the written test also obtained good results for the oral examination. In time, nearly all the students who sat for the examination passed the written test but, apart from some rare exceptions, they were not then able to explain, during their oral test, the choices they made in the written test.

The same phenomenon has been observed in applications for pharmacies: with the passing of time an ever increasing number of candidates passed the test. The teaching staff of the University of Bari have introduced changes to the structure of the questions in order to limit the contribution of memory and encourage the use of reasoning based on the knowledge of the discipline being examined.

After several approaches to the problem, the strategy that has appeared to be most successful is the sequential multiple choice question (SMCQ).

## Description

What is unique about SMCQs is that the five possible answers to a question are connected to one another on an approximation scale towards the most probable answer.

Here one must not simply indicate the correct answer but he must arrange the five answers on a scale from one to five where one is the least probable correct answer and five is the most probable correct answer. In this new approach, reasoning is necessary to set the five answers in their logical sequential order, thus limiting the possibility of the candidate answering merely on the basis of memory or by guessing.

This approach is mentioned in the literature by some authors (Denyer & Hancock, 2002) who proposed new formulations of questions in order to counteract students' tendency to copy. The authors have already taken into consideration some of the

favourable aspects of the SMCQs. Some examples of SMCQs, which may provide a better comprehension of the subject, have been recently published in a volume of the Pharmaceutical Press (Azzopardi & Tortorella, 2006) and on the University of Bari website (<http://xfiles.farmacia.uniba.it/quiz/sequenziali/index.php>).

With the SMCQs, the selection of the five answers is very different to that of the classic MCQs, where there is a 20% probability of answering correctly by chance. If a student has chosen the most correct answer, scored as 5, the final 'score' of the question will be substantially different in the case where the least correct answer (scored as 1) is provided as the second most correct answer (scored as 4) to one where it is second least correct answer (scored as 2). In these two cases the numerical differences (4 - 1 = 3) and (2 - 1 = 1) effect the final evaluation of the exam.

The score for the evaluation of every question is expressed by the formula:

$$12 + \sum_{i \rightarrow A}^E \widetilde{CGP}_i - \sum_{i \rightarrow A}^E |\widetilde{CP}_i - \widetilde{AGP}_i|$$

Where  $\widetilde{CGP}_i$  = correctly given precedence, that is, the value that the student correctly assigned to each option; it matches  $\widetilde{CP}_i$  and may range from 1 to 5.

$\widetilde{CP}_i$  = correct precedence, that is, the precedence that the student should give to each option in order to correctly allocate each option in the hierarchy set by the examiner who formulated the question; it may range from 1 to 5.

$i$  = index that indicates the answer; it may range from A to E.

$\widetilde{AGP}_i$  = actual given precedence, that is, the value given by the student to each option;

If  $\widetilde{CP}_i = \widetilde{AGP}_i$ , the student's answer is correct and  $\widetilde{CP}_i - \widetilde{AGP}_i = 0$ .

Thus, the final score is obtained by adding 12 to the sum of the values correctly given by the student to each option and subtracting the sum of the differences between the exact precedence of each option and the actual value given to the same option by the student. The scores for the 120 different possible combinations are reported in Figure 1.

## Evaluation

In principle, SMCQs should allow a more accurate evaluation of candidates than MCQs. In fact, considering the case where a candidate has been successful in selecting the highest precedence answer (precedence 5), he may reach one out of eleven possible final scores ranging from 9 to 27 (see the sequences in columns 1-9, 13-16, 18-20, 27-30 and 39-42 in Figure 1) depending on his ability to correctly select the hierarchy of the remaining four answers. In the experience acquired so far, we stated that in about 17% of the administered tests judged as not sufficient to pass the examination, the forth-ranking answer had been correctly located. In the MCQ framework these tests would have been considered correct and adequate to pass the examination.

combination number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
<b>CORRECT HIERARCHY:</b>	1	1	2	1	3	1	1	3	2	4	1	1	1	1	4	2	5	4	3	2	
	2	2	1	3	2	2	4	1	3	2	2	2	5	4	3	1	4	2	2	2	1
	3	3	3	2	1	4	3	2	1	3	3	5	3	2	4	3	3	3	1	4	4
	4	4	4	4	4	3	2	4	4	1	5	4	4	3	2	2	1	4	3	1	3
	5	5	5	5	5	5	5	5	5	5	4	3	2	5	5	5	5	1	5	5	5
<b>SCORE</b>	27	22	20	19	18	17	17	17	16	16	15	14	14	14	14	14	13	13	13	13	
cumulative probability	0.8	1.7	2.5	3.3	4.2	6.7		8.3		9.2	13.3			16.7							
correctly given precedences	5	3	3	3	3	3	2	2	3	3	3	3	2	2	2	2	3	2	2	1	

  

combination number	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	
<b>CORRECT HIERARCHY:</b>	1	1	1	1	5	2	4	2	3	2	2	2	5	1	3	1	5	4	3	4	3	4	1	
	2	2	2	5	3	1	5	1	4	1	3	1	1	2	4	2	5	2	2	4	3	4	3	3
	3	5	4	2	5	3	3	2	1	4	4	3	5	1	3	5	3	3	3	1	1	2	2	2
	4	3	5	4	4	4	4	3	3	2	1	5	4	4	5	4	2	1	5	2	2	1	1	5
	5	4	3	3	2	2	1	5	5	5	5	4	3	3	2	1	4	4	1	5	5	5	5	4
<b>SCORE</b>	11	11	11	11	11	11	11	11	11	11	11	10	10	10	10	10	9	9	9	9	9	9	9	
cumulative probability	25.8						30.0						35.8											
correctly given precedences	2	2	2	2	2	2	1	1	1	1	1	1	2	2	2	2	2	2	1	1	1	1	1	

  

combination number	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	
<b>CORRECT HIERARCHY:</b>	1	3	5	2	3	2	1	1	5	2	1	1	4	2	5	3	4	3	5	3	5	3	3	2	2	2
	2	2	1	5	1	3	5	3	1	5	4	3	1	4	2	2	2	5	3	5	3	1	2	3	1	1
	3	1	2	1	5	5	2	5	3	3	2	4	3	3	1	5	1	1	1	2	2	2	4	1	5	4
	4	5	4	4	4	4	3	2	2	1	5	5	5	5	3	1	5	4	4	4	4	5	5	5	3	5
	5	4	3	3	2	1	4	4	4	4	3	2	2	1	4	4	3	2	2	1	1	4	1	4	4	3
<b>SCORE</b>	8	8	8	8	8	7	7	7	7	7	7	7	7	6	6	6	6	6	6	6	6	6	6	6	6	
cumulative probability	40.0				46.7								56.7													
correctly given precedences	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	0	0	0	

  

combination number	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	
<b>CORRECT HIERARCHY:</b>	1	1	1	1	4	5	4	5	5	2	3	2	4	2	3	2	4	5	4	5	
	2	4	5	4	5	2	2	2	2	1	5	1	3	1	4	1	3	5	4	5	4
	3	5	4	5	4	5	4	5	4	2	1	5	5	2	1	4	4	3	3	3	3
	4	2	2	3	3	1	1	3	3	3	3	2	1	5	5	5	5	1	1	2	2
	5	3	3	2	2	3	3	1	1	4	4	4	4	3	3	2	1	2	2	1	1
<b>SCORE</b>	5	5	5	5	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	
cumulative probability	60.0				70.0								73.3								
correctly given precedences	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	

  

combination number	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	
<b>CORRECT HIERARCHY:</b>	1	3	5	3	5	4	5	2	2	3	4	4	5	3	4	2	2
	2	5	3	5	3	1	1	4	5	4	3	1	1	4	3	4	5
	3	1	1	2	2	5	4	5	4	1	1	5	4	2	2	5	4
	4	2	2	1	1	2	2	1	1	5	5	3	3	5	5	3	3
	5	4	4	4	4	3	3	3	3	2	2	2	2	1	1	1	1
<b>SCORE</b>	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
cumulative probability	86.7																
correctly given precedences	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

  

combination number	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	
<b>CORRECT HIERARCHY:</b>	1	4	5	4	5	4	5	3	4	3	5	4	5	3	4	3	5
	2	5	4	5	4	5	4	4	3	5	3	5	4	4	3	5	3
	3	1	1	2	2	1	1	5	5	4	4	2	2	5	5	4	4
	4	2	2	1	1	3	3	1	1	1	1	3	3	2	2	2	2
	5	3	3	3	3	2	2	2	2	2	2	1	1	1	1	1	1
<b>SCORE</b>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
cumulative probability	100.0																
correctly given precedences	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Figure 1. Possible combinations of precedences (columns 1-120) and corresponding scores (correctly assigned precedences are in grey cells).

The feature that students most appreciate is the possibility to 'construct' a plausible hierarchy starting from the bottom when the location of the most correct answer is difficult or strongly depending on mnemonic skills. Thus, one may well reach a relatively high final score simply starting from the correct location of the two lowest precedence answers (e.g., compare the final scores of column 21 or 22, with the ones of columns 39-42, in Figure 1). The final scores corresponding to columns 39-42 compared with the one of column 43 demonstrate that, depending on the position of the other four responses, the exact selection of either the best or the worst reply may give the same final score.

A further advantage of the SMCQs over the MCQs consists in the fact that they allow a profitable use of an oral examination after the written test. Such an oral examination should focus on the reasoning used by the candidate to attribute position  $X + 1$  (or  $X - 1$ ) to an answer that, according to the teacher, should have been in position  $X$ . In our experience this is an attractive SMCQ feature for both teachers and students.

Finally, given the high informative content of SMCQs, the number needed to evaluate each candidate may be around five times lower than that required for MCQs. However, in our experience, the time it takes to prepare SMCQs is significantly longer than that required for preparing MCQs.

## Implementation

The implementation of the internet site cited above is currently being developed as an electronic examination tool. In order to simplify the choice and implement the content of the different topics, the SMCQs will be organised by means of:

ATC classification of the drug involved  
their relation with the main disciplines in Pharmacy education  
illustrations, photos, tables, and animations supporting the treated subjects.

These SMCQs may be used as an examination tool by teachers who want to both evaluate their students on a certain topic and reduce students' tendency to copy. When repeatedly selecting the same exam, the software produces one of 120 different versions, with differing arrangements of the five responses. Thus, there is a minimal possibility that the same version is being used by students sitting close to one another.

In conclusion, SMCQs are extremely valuable in assessing students' knowledge. Moreover, evaluation suggests that students appreciate them more than traditional MCQs.

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