Mix-and-Match MCQs: Four for the price of one.

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ABSTRACT

Multiple choice questions are a popular means of assessment for online examinations: easy to mark, but difficult to prepare in a way that makes it hard for students to gain high marks by sharing answers between them. Here we describe a systematic approach for creating multiple choice questions that can be used to test the understanding of bookwork topics, while still being challenging and mitigating against potential cheating.

PREPARING MCQs

One result of the pandemic is that much assessment has been moved online and is therefore un-invigilated. Many educators have consequently explored multiple choice questions (MCQs) as a viable option, even for large weight final examination assessments. If all students were presented with the same questions it would be easy to share answers, so MCQ designers often use one or more of the following techniques:

- The order of the questions is randomized for each student
- The order of the options within each question is shuffled for each student
- A set of variants for each question is created, and a random variant is chosen for each student

It is the final technique that is addressed in this paper. We consider the problem of creating a set of **variants** for a **question**, such that each variant is of comparable difficulty and addresses the same learning outcome. For this to be the case, each variant needs to relate to the same topic; thus, there is a one-to-one correspondence between **question** and **topic**. We propose an approach that is particular to bookwork topics; that is, questions that test the understanding of 'declarative' knowledge.

Many intended learning outcomes in Computing Science relate to students' competence in writing, analysing, tracing, or extending algorithms, in performing calculations, or in following processes.

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It is relatively easy to create a set of variants for such 'procedural' or 'applied' questions (e.g., Fig. 1(a)), since they can be parameterized through a change of values, inequalities, structure etc. It is more difficult to create variants for declarative 'bookwork' knowledge (e.g., Fig. 1(b)), and when such questions are conducted in open-book mode, students typically need to simply consult the one place in the lecture notes where the answer is provided.

A NEW APPROACH FOR BOOKWOOK MCQs

Our proposed solution allows for 12 complex MCQs variants to be created for one bookwork topic, where each variant addresses three **facets** of a topic[1]. Thus, three different aspects of the topic need to be identified, and to identify the correct answer, students need to understand all three. The correct solution is therefore unlikely to be found in just one small section of the lecture notes.

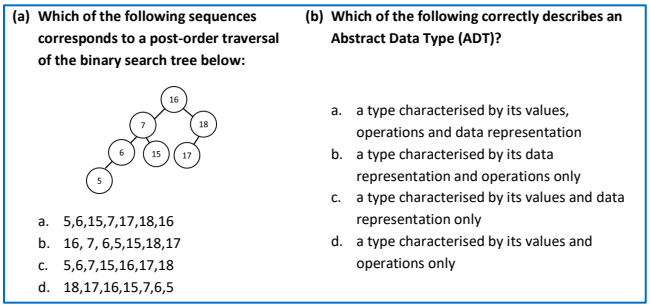


Figure 1: (a) Several different variants of this applied question would be easy to create. (b) It is more difficult to create several variants for this bookwork question.

For example, in the context of a course on Information Visualisation, Glyphs are visual objects that can depict several dimensions of data. There are three facets of Glyphs that we would like students to know about: their usefulness in representing multidimensional data (F1), the potential (but not mandatory) use of position on a 2D plane to represent attribute information (F2), and how their design relates to Bertin's Visual

[1] The approach could be extended to four or more facets, with the consequent combinatorial explosion of variants. It could similarly be extended to questions with more than two incorrect options, ditto.

variables (F3). We can create a simple MCQ for each facet, each having the same stem (Fig 2).

	stem	incorrect answer 1 (i1)	incorrect answer 2 (i2)	correct answer (c)
F1	Glyphs..	..can only represent data of one dimension	..can only represent data of four dimensions	..are one way of depicting multidimensional data
F2	Glyphs..	..are always stand-alone, and do not relate to location	..must be positioned carefully on the 2D plane if they are to have any meaning	..can be positioned on the 2D plane in a way that adds additional information
F3	Glyphs..	..only use the Bertin visual variables of colour, shape and orientation	..can be designed to use up to four of Bertin's visual variables to represent data points	..can be designed to use combinations of any of Bertin's visual variables to represent data points

Figure 2: One simple MCQ for each facet of a topic.

The three simple questions are just that: simple. Students need only look up the materials that relate to the one facet to find the solution - so, these questions are too easy for online open-book use, and the answers are easily shared. However, for each of the three correct answers, we can mix-and-match the incorrect answers, giving us four new (more complex) questions (Fig 3).

F1(i1)	F1(i2)	F1(c)
F2(i1)	F2(i2)	F2(c)
F3(i1)	F3(i2)	F3(c)

Figure 3: Pairs of incorrect options from F2 and F3 can be selected in four ways, with each pair presented as the alternative MCQ options for the same correct answer for F1.

There are therefore 12 separate question variants for the topic (four for each correct answer) (Fig. 4). Two variants for the Glyph question (appropriately shuffled) are shown in Fig. 5, and an alternative for the ADT question in Fig. 1(b) is shown in Fig 6.

using correct answer for F1	using correct answer for F2	using correct answer for F3
F2(i1), F3(i2), F1(c)	F1(i1), F3(i2), F2(c)	F1(i1), F2(i2), F3(c)
F2(i1), F3(i1), F1(c)	F1(i1), F3(i1), F2(c)	F1(i1), F2(i1), F3(c)
F2(i2), F3(i1), F1(c)	F1(i2), F3(i1), F2(c)	F1(i2), F2(i1), F3(c)
F2(i2), F3(i2), F1(c)	F1(i2), F3(i2), F2(c)	F1(i2), F2(i2), F3(c)

Figure 4: Each of the 12 variants addresses all three facets of the topic. Each student is randomly allocated one of these 12 variants.

Glyphs..

a. ..are always stand-alone, and do not relate to location
b. ..can be designed to use combinations of any of Bertin's visual variables to represent data points
c. ..can only represent data of four dimensions

Glyphs..

a. ..only use the Bertin visual variables of colour, shape and orientation
b. ..can only represent data of four dimensions
c. ..can be positioned on the 2D plane in a way that adds additional information

Figure 5: These two variants address the same three facets on the topic of Glyphs.

(a) An ADT…

a. …is characterized by its data representation and operations only
b. …needs data structure and algorithm choices to be made when implemented
c. …requires a contract that specifies which applications can use it

(b) An ADT…

a. …requires a contract that specifies its operations
b. …can be implemented using any algorithm together with any data representation
c. …is characterized by its values, operations and data representation

Figure 6: Two complex variants of the bookwork ADT question in Fig. 1(b).

IN PRACTICE

This method has been used in three courses, each with 24 questions, worth 20% of the students' final course grade, and conducted as an open-book exam using Moodle Quiz. The distributions of the grades (based on number of correctly answered questions[2]) are shown in Fig. 7. A longer exam duration and an extended pre-exam revision period for 7(a) may explain the differences in distribution.

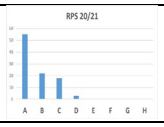
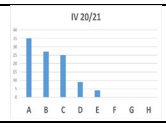
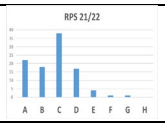
	(a)	(b)	(c)
			
mean	69.2%	63.2%	58.2%
median	71%	65%	58%
mode	75%	67%	54%
stddev	12.0	12.7	13.0

Figure 7: Percentage distribution of grades: (a) Research and Professional Skills 20/21; (b) Information Visualisation 20/21; (c) Research and Professional Skills 21/22.

These bookwork exams were certainly not trivial, and students were unable to share answers. Students reported that they were surprised at the questions being so difficult, and many of them had assumed that an 'open book multiple choice' exam does not require any advance revision.

This approach has the advantage of providing a large number of bookwork question variants of comparable difficulty which address the same learning outcomes within a topic. It relies on there being three facets to a topic that students should know, and on being able to express simple separate MCQs that relate to each facet using the same question stem. Neither of these requirements have proved difficult to satisfy in the two courses in which this method has so far been used successfully.

[2] Under our School's negative marking policy for MCQs, the actual grades awarded were lower than shown here.