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E-assessment by design: using multiple-choice tests to good effect

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Over the last decade, larger student numbers, reduced resources and increasing use of new technologies have led to the increased use of multiple-choice questions (MCQs) as a method of assessment in higher education courses. This paper identifies some limitations associated with MCQs from a pedagogical standpoint. It then provides an assessment framework and a set of feedback principles that, if implemented, would support the development of learner self-regulation. The different uses of MCQs are then mapped out in relation to this framework using case studies of assessment practice drawn from published research. This analysis shows the different ways in which MCQs can be used to support the development of learner self-regulation. The framework and principles are offered as a way of helping teachers design the use of MCQs in their courses and of evaluating their effectiveness in supporting the development of learner autonomy. A key message from this analysis is that the power of MCQs (to enhance learning) is not increased merely by better test construction. Power is also achieved by manipulating the context within which these tests are used.

Introduction

Multiple-choice questions (MCQs) are being increasingly used in higher education as a means of supplementing or even replacing current assessment practices. The growth in this method of assessment has been driven by wider changes in the higher education environment such as the growing numbers of students, reduced resources, modularisation and the increased availability of computer networks. MCQs are seen as a way of enhancing opportunities for rapid feedback to students as well as a way of saving staff time in marking. Computer networks enable more flexibility in the delivery of MCQs (e.g. with delivery at times and places more in tune with student needs) and, with appropriate software, they automate and speed up marking and the collation of test results. Compared to paper-based MCQs, the use of online computer-assisted assessment (CAA) can significantly reduce the burden associated with testing large student cohorts (Bull & McKenna, 2004).

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Although multiple-choice testing is widely used in higher education, there are recognised limitations with this method. Firstly, many researchers discourage the use of MCQs, arguing that they promote memorisation and factual recall and do not encourage (or test for) high-level cognitive processes (Airasian, 1994; Scouller, 1998). Some researchers, however, maintain that this depends on how the tests are constructed and that they can be used to evaluate learning at higher cognitive levels (Cox, 1976; Johnstone & Arnbusaidi, 2000). Secondly, the feedback provided through MCQs is usually quite limited as it is predetermined during test construction. Hence there is little scope for personalisation of feedback based on different student needs. Thirdly, the use of MCQs is usually driven by the need for teacher efficiencies and the provision of rapid feedback rather than by robust pedagogical principles aimed at encouraging effective learning. MCQs require the selection of a correct answer from a set of alternatives, i.e. the recognition of the answer rather than the construction of a response. In addition, students have no role in setting the goals and standards for MCQ tests, nor are they usually in a position to clarify the test question or its purposes while taking the test (i.e. clarify goals and standards). It is difficult therefore to envisage how this method of testing addresses current concerns in the assessment research that students should be given a more active and participative role in assessment processes (Boud, 2000; Yorke, 2003) or that assessment should develop in students the skills needed to self-regulate their own learning (Nicol & Macfarlane-Dick, 2006; Nicol & Milligan, 2006).

This article addresses the above issues. It first provides a framework comprising a set of principles for thinking about formative assessment and feedback that is grounded in current research. It then maps the use of MCQs in different assessment contexts into this framework and illustrates its value using case examples of practice drawn from the literature. This analysis helps enrich our understanding of the ways in which MCQs can be used to support the development of learner self-regulation. It is argued that a pedagogical or assessment framework is necessary if teachers are to design effective uses for MCQs in their courses or if they wish to evaluate their effectiveness. An assessment framework not only helps teachers analyse the effective uses of MCQs but it also helps them move beyond the narrow conception that MCQs are either good or bad. The case studies illustrate that what is important is not just the content and format of MCQ tests but the wider context within which they are used.

Assessment for learning: framework and principles

In 2006, Nicol and Macfarlane-Dick analysed a large body of research in the area of formative assessment and feedback in order to identify how these processes could help enhance the development of self-direction and a reflective approach in learners. From this analysis they were able to identify seven principles of good feedback practice that, if implemented, would support the development of learner self-regulation. Each principle is defined in detail in Nicol and Macfarlane-Dick (2006) alongside the supporting research and recommendations for practice. Figure 1 briefly presents the seven feedback principles:

Good feedback practice:
(1) helps clarify what good performance is (goals, criteria, standards);
(2) facilitates the development of self-assessment and reflection in learning;
(3) delivers high-quality information to students about their learning;
(4) encourages teacher and peer dialogue around learning;
(5) encourages positive motivational beliefs and self-esteem;
(6) provides opportunities to close the gap between current and desired performance;
(7) provides information to teachers that can be used to help shape teaching.

Figure 1. Seven principles of good feedback practice

The work of Nicol and Macfarlane-Dick is consistent with that of other researchers who have emphasised the need to develop autonomy in learning (Boud, 2000) and to involve students as active participants in assessment processes (Brew, 1999). The seven feedback principles are not new: their value is that each principle is supported by a substantial body of research, that they are all defined in relation to their contribution to the development of learner self-regulation, and that taken together they provide a clear lens through which to design and evaluate practice. It should be noted here that feedback is defined broadly and encompasses informal and formal processes including the learner generating their own feedback (e.g. through self-assessment) and peer processes.

There is little space here to discuss each principle in detail but a few key findings are important. Firstly Principle 1 underpins all the others. In order to self-regulate their own learning, students must have a reasonable understanding of what is required in assessment tasks (i.e. their understanding must overlap with that of their teacher's). Yet there is considerable research linking poor performance by students to a failure to grasp assessment requirements (Higgins *et al.*, 2001; Rust *et al.*, 2003). Secondly, the principles emphasise the power of dialogue in learning; self-regulation is facilitated when learning involves the active construction of knowledge through group interaction, peer feedback and discussion (Brew, 1999; Boud, 2000). Thirdly, self-regulation requires motivation and a belief that effort will produce results. Research shows that motivation is neither fixed nor completely determined by the environment and that students construct their motivation based on their appraisal of the learning and assessment context (Paris & Turner, 1994). However, teachers can influence this appraisal through targeted interventions such as providing many low-stakes feedback opportunities, by fostering learning communities, by focusing students on learning goals rather than marks and by linking formative tasks to summative assessments (Nicol & Macfarlane-Dick, 2006). MCQs are not normally associated with research findings of this kind nor with the seven feedback principles. However, the following analysis attempts to show the value of making such an association.

Overview of application of seven principles in relation to MCQs

Figure 2 summarises the ways in which multiple-choice tests can be used to support learner self-regulation based on the seven feedback principles. The case studies which follow provide worked examples of application drawn from the research literature. In the case studies, the feedback principles are identified within actual

1. Clarifying goals, criteria and standards
In this scenario, students don't just engage with MCQs as test-takers but they construct the tests themselves. This ensures that they are actively engaged in generating both the criteria for the tests and the trigger questions. Case Study 4 exemplifies the power of this process.

2. Self-assessment and reflection
In this scenario, MCQs might be administered in an open-book situation (i.e. where students can look up answers). This allows students to self-assess and self-correct during a testing session (see Honey & Marshall, 2003). The quality of the questions would be important here: they should go beyond the simple selection of words from texts. An example of additional reflection would be where students provide a confidence rating alongside their MCQ response. This encourages students to step back and reflect on the thinking behind their answer, as illustrated in Case Study 2.

3. Delivers high-quality feedback
Students often receive teacher-prepared feedback during MCQs but this feedback is limited, to the extent that it is predefined during test construction. However, tutor feedback can be enhanced through links to other classroom activities. For example, tutors might use seminars or tutorials to go over areas where students have experienced difficulty based on their performance in prior MCQs. This is exemplified in Case Study 1.

4. Encourages dialogue around learning
Peer dialogue is important way of scaffolding learning but MCQ tests are usually available as an individual activity. The power of tests can be increased by having students work in small groups to construct tests or to comment on some aspect of tests that are already constructed (e.g. MCQs in a prior examination paper). Another strategy is to have students discuss their answers to MCQs as they are taking the test (e.g. by randomising the questions so that each student has a different test) or to initiate a class discussion of answers to tests as described in Case Study 3.

5. Feedback and motivation
In this scenario, students are given repeated opportunities to take MCQ tests, often staged over the timeline of the course. Research shows that this is highly motivating. Motivation appears to be further enhanced when this formative procedure is linked to later summative tests of a similar format (see Zakrzewski & Bull, 1999).

6. Closing the gap
In this scenario, students can repeatedly take MCQs and check answers until they reach a satisfactory performance. This provides opportunities to close the gap between current and desired test performance.

7. Feedback shaping teaching
MCQs might be presented before students come to a lecture and even linked to homework assignments. The teacher can then use the results of the tests to identify areas of learning difficulty and to decide where to focus teaching effort in class or in further online tasks (a form of 'just-in-time teaching').

Figure 2. Mapping the use of MCQs to the seven principles of good feedback practice

learning designs. The first two case examples highlight the operation of one or two principles. However, considerable power is gained when a number of feedback principles are combined within the same learning design. Case studies 3 and 4 show ways in which this combination can be achieved.

Case study 1: fundamentals of human physiology

A typical use of MCQs is with first-year courses with large numbers of students. Bull and Danson (2004) describe a 'fundamentals of human physiology' module

intended to prepare students for their second year of study. Before the introduction of MCQs there were three coursework assignments. Although many students passed these three assignments, many still failed the examination. Part of the problem was that the feedback was coming too late, halfway through the module. MCQs were introduced as a replacement for one of the assignments and comprised a series of five computer-delivered multiple-choice tests staged through the duration of the module. Each test was related to the teaching material for the previous two weeks of lecturing and the students received feedback on their answers after each test. More importantly, the lecturer examined which questions students had performed poorly on and used this information to provide extra feedback support in those specific areas at a subsequent seminar. Bull and Danson (2004) report that 'through the feedback students gained a clear idea of how they were progressing with the course and were motivated to follow up some of the feedback suggestions regarding further reading and research' (p. 10).

Commentary on Case 1

In this case example, the teacher uses MCQs to achieve a variety of different objectives. Traditional uses of MCQs implemented here are to enable students to self-test their understanding (Principle 2, *self-assessment*) and to provide immediate feedback on their answers (Principle 3, *feedback*). The staging of the tests also keeps students engaged in productive activities during the timeline of the module (Principle 6, *motivation*). However, this example also shows the way that the power of multiple-choice tests for learning can be enhanced.

Extra power in this example is achieved by integrating MCQs with other learning activities, thereby activating additional feedback principles. The lecturer uses the results of the students' performance on the tests to frame the seminar discussion (Principle 7, *feedback shapes the teaching*) and to provide extra dialogical feedback in the seminars (Principle 4, *dialogue*). This is an example of what Novak *et al.* (1999) call 'just in time teaching'.

Case study 2: medicine

In this example, Gardner-Medwin (2006) uses online MCQs during the first two years of a medical degree at University College London. However, he has introduced a critical modification called 'confidence-based marking' (CBM). In CBM students not only select the answer but they also rate their confidence on a three-point scale (C=1, 2 or 3). Both these components determine the mark as shown in Table 1. When the answer is correct the mark depends on the confidence level (M=1, 2 or 3). If the answer is wrong, then the higher the confidence level the higher the penalty (-2 at C=2 and -6 at C=3). This procedure encourages students to think deeply about their own knowledge and about whether they have a reliable reason for choosing the answer. In effect, students must be able to justify their answer (internally) before it is sensible to risk a penalty for high confidence.

Table 1. Scoring regime for certainty-based marking

Degree of Certainty	Low	Medium	High	No reply
Mark if correct	1	2	3	0
Penalty if wrong	0	−2	−6	0

Commentary on Case 2

Gardner-Medwin (2006) relates CBM to the second and the fifth principles of good feedback practice. Firstly, by having to rate their confidence students are forced to reflect on the soundness of their answer and assess their own reasoning (Principle 2, *reflection/self-assessment*). Secondly, regular use of this procedure both formatively and in the final examinations increases students' confidence in their knowledge (Principle 5, *motivation*) and encourages regular practice of these tests online. Importantly, CBM does not require that the teacher actually collect or analyse the reasons underlying students' answers. It is therefore surprising that it is not more widely used.

Case study 3: interactive mechanics

The next case example is still about the use of MCQs but this time their application is supported through two technologies—electronic voting systems (EVS) and the assessment tools in a virtual learning environment (WebCT).

Eight years ago, at the University of Strathclyde, staff in the Department of Mechanical Engineering made a radical change in their teaching methods for first-year students (see Boyle & Nicol, 2003; Nicol & Boyle, 2003). The standard lecture/tutorial/laboratory format was replaced by a series of two-hour active learning sessions involving short mini-presentations, videos, demonstrations and problem-solving all held together by MCQ tests linked to peer instruction. Peer instruction is a form of 'teaching by questioning' pioneered by Mazur at Harvard (1997) using electronic voting technologies.

A typical peer instruction class, interactive mechanics, begins with the teacher giving a short explanation of a concept or providing a video demonstration of the concept (e.g. force in mechanics). This is followed by a multiple-choice question test. Students respond to the MCQs using handsets (similar to a TV remote) that send signals (radio frequency or infrared) to receivers linked to a computer. Software collates responses and presents a bar chart to the class showing the distribution across the alternatives. In peer instruction, if a large percentage of the class have incorrect responses, the teacher instructs the class to: 'convince your neighbours that you have the right answer'. This request results in students engaging in peer discussion about the thinking and reasoning behind their answers. After the discussion the teacher normally retests the students' understanding of the same concept. Another strategy is for the teacher to facilitate 'class-wide discussion' on the topic by asking students to explain the thinking behind their answers. The EVS

sequence usually ends with the teacher clarifying the correct answer. There are many other ways of using EVS to facilitate interaction and collaboration and this technology has been used across a range of disciplines.

More recent developments involve the integration of online MCQs with the classroom use of EVS. Students are presented with online MCQs before the EVS session. The teacher uses the results of these online tests to ascertain areas of misunderstanding and to determine the focus for the EVS sessions. As with Case 1, 'just-in-time teaching' (Novak *et al.*, 1999) helps target teaching to students' needs. A second innovation is the use of confidence-based marking (CBM) during EVS sessions. This uses MCQs but students must rate their confidence (certainty) in their answer. This is being piloted as formative assessment using the marking rules in Table 1 with the intention of using this as a final assessment method at a later time. CBM requires that students engage in some meta-cognitive thinking, i.e. it requires them to step back and reflect on whether there is good justification for their answer (Gardner-Medwin, 2006).

Commentary on Case study 3

The use of multiple-choice tests in and out of class in interactive mechanics is a powerful example of an integrated implementation of the seven principles of good feedback.

(1) Learning goals are clarified through iterative cycles of tutor presentation and the testing and retesting of concepts using MCQs in class (Principle 1).
(2) Opportunities for self-assessment and reflection are available when the teacher provides the concept answer at the end of the EVS test sequence. Students also reflect on their answer during confidence-based marking. Reflection is also possible after the bar chart presentation of class response (Principle 2).
(3) Teachers normally provide feedback during class in response to students' questions and at the end of each concept test-discussion sequence to clear up any misunderstandings (Principle 3).
(4) Peer dialogue is integral to both peer instruction and class-wide discussion. Specific tutor–student dialogue occurs during class-wide discussion (Principle 4).
(5) The EVS class focuses on learning goals rather than performance goals (i.e. grading) and there is a step-by-step progression in the difficulty of the concept questions. Both processes are known to enhance motivation (Principle 5).
(6) The continuous cycle of tests, retests and feedback ensures that students have opportunities to 'experience' a closing of the gap between desired and actual performance (Principle 6).
(7) A great deal of information is available to the teacher about areas of student difficulty that is used to shape in-class teaching. The bar chart gives the teacher instant feedback on difficulties and asking students to explain answers during class-wide discussion also uncovers conceptual misconceptions. The

information provided through the web-based MCQs also informs in-class teaching (Principle 7).

Extensive evaluations have been carried out in engineering mechanics showing significant learning gains (Boyle & Nicol, 2003; Nicol & Boyle, 2003). Overall the changes have been a huge success both in terms of student end-of-year performance in exams and in terms of retention. There has been a reduction from 20% non-completion to 3%, the largest gain in any course within the university. Also, since the introduction of concept tests with electronic voting, attendance at class remains high throughout the year (unlike similar lecture-based classes). Further evaluations of confidence-based marking are now being carried out. While there is a great deal of research on the benefits of using of EVS to support learning (see Banks, 2006), this is the first analysis from a formative feedback perspective. This analysis provides new insights into how the different component processes (self, peer and tutor feedback) interact and reinforce each other in a single setting.

Case study 4: organisational behaviour

A key issue in the literature on formative assessment is how to move students from being dependent on teacher feedback to being able to generate their own feedback on learning. While the case examples above begin to address this issue by engaging students in reflective activities and in peer dialogue, there are still some limitations with these methods. One issue concerns the balance of learner self-regulation and teacher direction. In the first three case examples, the teacher is still primarily in control of the students' learning. It is the teacher who sets the MCQ tests and the students' role is merely to respond by selecting an answer: they don't actively construct answers. Hence these approaches do not address current concerns that in order to develop the self-regulatory skills required for lifelong learning, students must actively participate in the construction of assessment criteria. Indeed in professional practice, experts both create the criteria that apply to their work and assess their performance against these criteria (Rust *et al.*, 2005). Higher education should help develop this capability.

One way of addressing the above issue is to have students construct MCQs rather than respond to those created by others. This was the approach taken by Fellenz (2004). He actively engaged students in generating assessment criteria and example questions within a course on organisational behaviour. Fellenz already had experience of using MCQs to assess content learning but he was seeking ways of using MCQs to support higher level and meta-learning. He also argued that traditional MCQs gave primacy to the instructor perspective and did not reflect partnership-based and learner-centred education philosophies.

Fellenz (2004) developed what he called the 'multiple-choice item development assignment' (MCIDA). Students were briefed on MCQ construction and in tutorials they had opportunities to discuss, question and critique MCQs and to learn how to classify them in relation to Bloom's (1956) taxonomy of educational objectives. (MCQ developers often use Bloom's taxonomy to categorise MCQ items as testing

for knowledge comprehension, application, analysis, synthesis and evaluation. These six categories form a hierarchy with knowledge being the lowest level and evaluation the highest.) After this induction, students were required to create three sets of MCQs in pairs over the timeline of the course and in relation to the course content. Specifically, they had to produce the question stem for each multiple-choice question and one correct and three incorrect answers including the written feedback comments for all four possible responses. After submission students received peer feedback on their MCQ items from other students on the quality of design and the accuracy of, and the justifications for, the feedback answers. Twenty percent of the course grade was determined by the MCIDA. Over half of the submitted MCQ items were later used in the end-of-term exam.

Commentary on Case 4

The following is an analysis of this course in relation to the seven feedback principles:

(1) Students create the MCQs by themselves, hence they must actively formulate the question in relation to the subject content and determine the assessment criteria. (This is a powerful implementation of Principle 1.)
(2) Students construct answers for correct and incorrect responses in relation to the multiple-choice questions. They also evaluate their MCQs against the Bloom taxonomy (Principle 2).
(3) The tutor monitors the construction process and provides general feedback (Principle 3).
(4) Peer dialogue and feedback are provided during MCQ creation in pairs and through tutorial meetings where items are discussed (Principle 4).
(5) The MCQs are used in the final examination and the MCQ construction process encourages peer sharing and engagement. Both processes enhance motivation and self-belief (Principle 5).
(6) The development of the items is cyclical with early feedback being used to improve performance on the later items (Principle 6).
(7) Teaching could be shaped by the developing MCQ outputs, although Fellenz does not mention this in his paper (Principle 7).

Fellenz (2004) has evaluated his use of the MCIDA through class discussion and through end-of-course questionnaires. Students report that the MCIDA helps develop a deep understanding of the course material and encourages collaborative learning. Fellenz found that the quality of the submitted MCQs improved over time and that asking the students for justifications for why answer options are correct or incorrect resulted in a very powerful learning experience. Students had to evaluate the course content, construct questions and provide compelling arguments in the feedback justifications. This required that they made 'explicit their understanding of the complexities of the subject matter' (p. 711). Fellenz also reported that his procedure 'increases student ownership of the assessment procedures used and

motivates students to participate' (p. 706). Fellenz did not use technology to support his MCIDA process but it easy to envisage how an online assessment tool might be used to support the sharing of MCQs and the peer feedback processes he describes. Indeed, a recent example of students contructing and sharing MCQ tests using the Blackboard virtual environment has just been published by Arthur (2006).

Discussion

Fellenz paid significant attention to ensuring that the MCQs produced by his students were of a very high quality. This required considerable work from the teacher in preparing students to create these tests and in assessing them against a range of criteria. However, Fellenz did not report from which year of study his students were drawn. In our own work with a first-year cohort we have taken the view that students don't need to produce extremely high-quality tests as this is something that even teachers find difficult. Our focus is not the output but the learning process. Hence, what is important is that the students engage in test construction and make a reasonable attempt. If the teacher has the skill she/he can select from those produced by students, and/or build on them for the final examination. This would still provide some opportunities to create a databank of reusable MCQ resources that could be used with other student cohorts, which is one of the advantages of the MCIDA procedure.

A key point of note from the case studies described above is that it is the learning and assessment design that is the driver for change rather than the technology. In Case study 3, classroom interaction of the kind described would not be have been possible without EVS yet it is the increased opportunities for self, peer and tutor feedback that actually produces the learning gains. Similarly, Case study 4 began with a powerful assessment design based on learner self-regulation. In our own work the application of technology has been used to enhance self-regulation through increased opportunities for resource sharing but within a similar assessment design to that of Case study 4 (www.reap.ac.uk). Students share MCQ tests during their construction, comment on them and give each other online feedback. In addition, the availability of these tests online makes it easier for students to access them when they are revising for their final examination. In both these case examples although the driver is the assessment design, the technology does afford significant enhancements.

In the assessment literature, considerable attention has been directed at the limitations of MCQs in testing for higher-order cognitive abilities and at how one might remedy this situation (Airasian, 1994). However, much less attention has been given to the wider learning context in which MCQs are used and their underpinning pedagogy. This article has shown that increased power can be leveraged from MCQs when they are linked to a clear pedagogical goal (in this case, the development of learner self-regulation) and implemented in relation to a coherent set of principles (the seven principles of good feedback practice). While the writer of this article believes that self-regulation encapsulates current thinking regarding the purpose of

assessment practices in higher education, other pedagogical frameworks might be applied. For example, other researchers might be interested in how MCQs might be used to support 'social learning' and they might apply a framework based on social constructivist pedagogy. However, what is meant by effective social learning would still have to be unpacked and defined, rather as the seven principles have been defined, if this construct were to guide MCQ use. Finally, while the framework in this article has been applied specifically to MCQs, the arguments made are generalisable to other kinds of objective tests, and even to other methods of assessment (see Nicol, 2006).

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