KEN HOUSTON

ASSESSING UNDERGRADUATE MATHEMATICS STUDENTS

1. INTRODUCTION

Any discussion of assessment must necessarily include a discussion of the curriculum, how it is designed and organised, and what it contains. It must examine the aims of the course that students are taking, and the objectives set for that course and the individual modules that comprise the course. (Here I am using terminology common in the UK. The 'course' students take is 'the whole thing', the 'programme'. A course in this sense consists of 'modules' or 'units', commonly called 'courses' in the USA, so beware of confusion!) The discussion must consider who is doing the assessing, why they are doing it, what they are doing and how it is being done. It must consider how assessors become assessors and how those assessed are prepared for assessment. And it must consider if the assessment is valid and consistent, and if it is seen to be so.

It might also be useful at this stage to define what we mean by a 'mathematician'. There is a real sense in which almost everyone could be described as a mathematician in that they make use of some aspect of mathematics – be it only arithmetic or other things learnt at primary/elementary school. The term could be used of those who have taken a first degree in mathematics and who use it in their employment. Or it could be reserved only for those who have a PhD and who are doing research in pure mathematics or an application of mathematics. We will use the middle of the road term. In other words, a mathematician will be one who has studied the subject at least to bachelors degree standard (and of course that varies across the world!), and who is using some aspect of advanced mathematics in their work. Such people could join a professional or learned society such as the UK based Institute of Mathematics and its Applications. So we are primarily concerned with the higher education of these people who can rightly be considered to be professional mathematicians. But also there are many disciplines wherein mathematics is an extensive and substantial component of study. Examples are physics or electronic engineering. The mathematical education of professionals in such fields as these could also come under the remit of this article in that many of the suggestions made could enhance the teaching, learning and assessment of students in these fields.

Traditionally assessment in higher education was solely summative and consisted of one or more time-constrained, unseen, written examination papers per module. A typical, and in some places predominant, purpose of assessment was to put students in what was believed to be rank order of ability. Students were, perhaps,

Derek Holton (Ed.), The Teaching and Learning of Mathematics at University Level: An ICMI Study, 407—422.

asked to prove a theorem or to apply a result, or to see if they could solve some previously unseen problem. Generally this method succeeded in putting students in a rank order and in labelling them excellent, above average, below average or fail. But was it rank order of ability in mathematics or rank order of ability to perform well in time-constrained, unseen, written examination papers? Sadly it was the latter, and while the two may coincide, this is not guaranteed. Taking time-constrained, unseen, written examination papers is a rite of passage, which students will never have to do again after graduation and which bears little relationship to the ways in which mathematicians work. While it is true that working mathematicians are sometimes under pressure to produce results to a deadline, the whole concept of time-constrained, unseen, written examinations is somewhat artificial and unrelated to working life.

It is in this context that people started to think about change, change in the way courses are designed and organised, change in the way course and module objectives are specified and change in the way students are assessed and in the way the outcomes of assessment are reported. It is usually the case that 'what you assess is what you get', that is, the assessment instruments used determine the nature of the teaching and the nature of the learning. Learning mathematics for the principal purpose of passing examinations often leads to surface learning, to memory learning alone, to learning that can only see small parts and not the whole of a subject, to learning wherein many of the skills and much of the knowledge required to be a working mathematician are overlooked. In time-constrained, unseen, written examinations no problem can be set that takes longer to solve than the time available for the examination. There are no opportunities for discussion, for research, for reflection or for using computer technology. Since these are important aspects of the working mathematician's life, it seems a pity to ignore them. And it seems a pity to leave out the possibilities for deep learning of the subject, that is, learning which is consolidated, learning which will be retained because it connects with previous learning, learning which develops curiosity and a thirst for more, learning which is demonstrably useful in working life.

This is, of course, a caricature of 'traditional' assessment, but it is not too far from the truth, and it brings out the reasons why some people in some societies became unhappy with university and college education. Consequently those who educate students now pay attention to stating aims and objectives, to redesigning curricula and structures and to devising assessment methods which promote the learning we want to happen and which measure the extent to which it has happened. And they pay attention to the need to convince students and funding bodies that they are getting good value for their investment of time and money.

The discussion on course design and assessment is also tied up with the discussion on 'graduateness'. What is it that characterises college or university graduates and distinguishes them from those who are not? Is it just superior knowledge of a particular topic, or is it more than that? It is, of course, more than that. It is not easy to define or even to describe, but it has to do with an outlook on life, a way of dealing with problems and situations, and a way of interacting with other people. (This is not to denigrate the learning that non-college graduates get from 'the university of life', nor to suggest that they are inferior as people. It is to do with considering the 'added value' of college or university education.) Traditionally graduateness was absorbed, simply through the university experience, but now that we have systems of mass education in many countries of the world, we need to pay attention to the development of graduate attributes in students so that they do, indeed, get value for money. In many instances, and mathematics is no exception, it is the 'more than' that is important when it comes to finding and keeping employment. Subject knowledge is important but so also are personal attributes. It is highly desirable that students develop what have come to be known as 'key skills' while they are undergraduates, and not just because employers are saying that the graduates they employ are weak in this area. Innovative mathematics curricula seek to do this by embedding the development of key skills in their teaching and learning structures. (Key skills are often described as employability skills or transferable skills. They include such skills as written, oral and visual communication, time management, group-work and team-work, critical reflection and self assessment, and computer and IT, and aural skills.)

Who are the stakeholders in an undergraduate's education? First and foremost are the students themselves. They are investing time and effort and they want to know that they are getting a return on this investment. Most of them realise that it is not enough for them to be given a grade; they know that they have to earn it. So they need to know what performance standards are required and they need to be able to recognise within themselves whether they have achieved these standards or not. This raises the question of self-assessment and ways of promoting self-assessment. Giving 'grades that count' is one way of encouraging students to carry out tasks.

The next stakeholder to consider are the teachers. It is their job to enable learning and so they need to know what learning has taken place. Financial sponsors of students are also stakeholders. They, too, want to know if they are getting a good return on their investment. Finally, in the stakeholder debate, there is a demand from society, students themselves, universities, prospective employers, that students be summatively assessed, ranked and labelled in such a way that they may be measured, not just against what they are supposed to have learned, but also against their peers across the world.

This chapter will consider all of these features, but will focus on assessment, as that is its theme. It will look at the purposes and principles of assessment and then it will move on to consider the aims and objectives of courses and modules. Innovative methods of assessment will be reviewed and discussed, and this will be the biggest part of the chapter. Ways of disseminating information about new assessment practices will be discussed, as will obstacles to change. Finally pertinent research issues will be mentioned. The chapter will close with an annotated bibliography of pertinent books and papers dealing with these issues.

2. PRINCIPLES AND PURPOSES OF ASSESSMENT

Perhaps the only principle that should be applied is 'fitness for purpose'. To achieve this, assessment methods should be intimately related to the Aims and Objectives of the Module under consideration. And it should be born in mind that the assessment methods used will influence the learning behaviour of students to a considerable extent.

There are a number of purposes of assessment that should be considered:

1. to inform learners about their own learning.
2. to inform teachers of the strengths and weaknesses of the learners and of themselves so that appropriate teaching strategies can be adopted.
3. to inform other stakeholders – society, funders, employers including the next educational stage.
4. to encourage learners to take a critical-reflective approach to everything that they do, that is, to self assess before submitting.
5. to provide a summative evaluation of achievement.

3. AIMS AND OBJECTIVES

Aims and objectives should be established both for a course and for each of the modules that comprise the course. The aims of a course are statements that identify the broad educational purposes of the course and may refer to the ways in which it addresses the needs of the stakeholders. Here are some examples; there are, of course, many more and each provider must write their own:

1. To provide a broad education in mathematics, statistics and computing for students who have demonstrated that they have the ability or who are considered to have the potential to benefit from the course.
2. To develop knowledge, understanding and experience of the theory, practice and application of selected areas of mathematics, statistics, operations research and computing so that graduates are able to use the skills and techniques of these areas to solve problems arising in industry, commerce and the public sector.
3. To develop key skills.
4. To provide students with an intellectual challenge and the practical skills to respond appropriately to further developments and situations in their careers.
5. To prepare students for the possibility of further study at post graduate level, including a PhD programme or a teacher training programme.

It would be necessary to indicate how each of the modules selected for a course helps to achieve the aims of the course. The aims of the individual modules should 'map' to the overall aims of the course. Objectives are statements of the intended learning outcomes that would demonstrate successful completion of the course or module, and that would warrant progression through the course and the eventual award of a degree. Module objectives should identify the knowledge, skills and attributes developed by a module, and course objectives should identify the knowledge, skills and attributes developed by the totality of modules selected for the course. Objectives may include reference to subject knowledge and understanding, cognitive skills, practical skills and key skills. They should be clearly relevant to fulfilling the aims and, above all, they should be assessable, that is, we should be able to devise assessment instruments that allow students to demonstrate that they have achieved the learning intended, and, if appropriate, to what extent. Here are some examples of course objectives: -

On completion of their studies graduates will have:

1. an understanding of the principles, techniques and applications of selected areas of mathematics, statistics, operations research and computing.
2. the ability and confidence to analyse and solve problems both of a routine and of a less obvious nature.
3. the ability and confidence to construct and use mathematical models of systems or situations, employing a creative and critical approach.
4. effective communication skills using a variety of media.
5. effective teamwork skills.

A course document should demonstrate how the aims and objectives of the constituent modules contribute to the overall course aims and objectives. Here is an example of the aims and objectives of a module, taken from an introductory module on mathematical modelling. (These aims and objectives are those of module MAT112J2, University of Ulster. Full details may be read under 'Syllabus Outline' at http://www.infj.ulst.ac.uk/cdmx23/mat112j2.html.) Note that an indication of the method of assessment of each objective is given.

Aims: The aims of this module are to:

1. enable students to understand the modelling process, to formulate appropriate mathematical models and to appreciate their limitations.
2. develop an understanding of mathematical methods and their role in modelling.
3. study a number of mathematical models.
4. develop in students a range of key skills.

It can be seen how these module aims help to meet the aims of the course listed above. Thus this module contributes to developing mathematical understanding, problem solving, and key skills.

Objectives: On completion of this module, students should be able to:

1. Formulate mathematical models and use them to solve problems of an appropriate level. (Assessed by coursework and written examination.)
2. Solve simple differential equations using calculus and computer algebra systems. (Assessed by written examination.)
3. Describe and criticise some mathematical models. (Assessed by coursework.)
4. Work in groups and report their work in a variety of media. (Assessed by coursework.)
5. Work both independently and in support of one another. (Assessed by coursework.)
6. Demonstrate other key skills. (Assessed by coursework.)

http://www.springer.com/978-0-7923-7191-5

The Teaching and Learning of Mathematics at University Level
An ICMI Study
Holton, D. (Ed.)
2001, VIII, 562 p., Hardcover
ISBN: 978-0-7923-7191-5