Mapping University Mathematics Assessment Practices

Edited by

Paola Iannone
University of East Anglia

Adrian Simpson
Durham University

National HE STEM Programme

The Higher Education Academy Maths, Stats & OR Network

Chapter 18
Evaluating Assessment Practices in a Business and Industrial Mathematics Module

Edmund Chadwick and Oana Radu

Abstract *Business and Industrial Mathematics* at the University of Salford is a second year module in the mathematics undergraduate degree. This 20 credit module spans two semesters and the assessment is 100% coursework. A variety of assessments and delivery modes is used. Examples include open-ended problems, problem solving, group work, presentations, report writing, employer seminars and professional studies. The aim of the evaluation study presented here is to investigate the students' perceptions of the various assessments and assessment practices used. We both obtained quantitative measures of the views of the different attributes of the assessments and heard the students' voices in their written comments on the practices they encounter.

18.1 Background and rationale

Business and Industrial Mathematics does not follow the traditional, closed book examination academic route; instead a variety of approaches is used to reflect practices in the workplace for mathematicians. The module aims to prepare students for employment and to highlight the way in which students are expected to use their mathematical knowledge in their future careers and thus the module assesses students for skills related to the workplace (Chadwick, 2011; Chadwick, Sandiford and Percy, 2011). A vital part of this is achieved by exposure to and understanding and experience of work related mathematics.

Throughout the module, seminars from guest speakers on a spectrum of mathematical applications used in industry expand the real world context and give students insights into the world of work and the ways mathematics may be used in their

Edmund Chadwick, e-mail: `e.a.chadwick@salford.ac.uk`
School of Computing Science and Engineering
University of Salford

Oana Radu, e-mail: `o.radu@uea.ac.uk`
School of Education and Lifelong Learning
University of East Anglia

jobs. These speakers represent a range of different employment sectors and include: DSTL, CMS Intelligent Banking, Manchester Medical Academic Health Sciences (NHS), IBM, an expert court case witness, IMA and the Sellafield OR group. Apart form describing what they do, the guest speakers also describe the group structure of their companies. Talks include topics related to career paths, company profiles and use of mathematics within companies.

These industrial partners identify a number of different attributes which they see as having vital importance, including teamwork, problem solving and professionalism and thus the module attempts to address these attributes in the assessments. There are four different assessments used.

The first is based on teamwork. Students are divided in groups of four, and every member of the group is given a different role: chair, secretary, technical coordinator and task coordinator. Each has responsibilities for particular sections in the final report and the structure attempts to mirror the small team-based approach used by many companies. Two open ended work-related problems are addressed, and each requires the development of a mathematical model. The deliverables include a report detailing the mathematical model, a minutes' book, a project plan and a presentation. The presentation is given to an audience of industrialists, and each team member contributes to it. Following these presentations the audience offers immediate feedback and helps rank the presentations. The academic adviser plays a supportive role and is required only to respond to questions from the group. After the first problem, the team roles are changed to give students greater exposure to different functions. The academic adviser also observes and notes the interaction between members of the groups, how they adapt to their given roles and the change in roles between case studies. Students are given input into the marking, and each student rates the contribution of each team member. From this, individual marks are derived from the group marks. Both the adviser and the students are required to share reflective comments on this experience as part of a wider personal development process for students.

The second assessment focuses on class-based brainstorming to solve a problem. For this part the module leader starts the discussion on the whiteboard by presenting some ideas. The class is encouraged to contribute their own ideas and thoughts. Thus, the whole class contributes to tackling the problem. Each week, a different lecturer leads with his/her ideas and contributions. Each student creates a final report. Thirty percent of this assignment comes from students' in-class contribution to the brainstorming sessions, with the remaining seventy percent from the report.

The third assessment focuses on problem solving abilities. Students are given a bank of games and puzzles. Each week they are able to play these amongst themselves and also take them out on loan. They then focus on particular one of interest to them, and write about the particular game/puzzle in a report. The idea is for the student to be able to describe the position, moves, tactics and strategies for a solution. The description is in the form of a report that represents seventy percent of the total mark. The other thirty percent of the mark comes from their involvement as assessed at the weekly meetings by the module coordinator.

A final assessment is focussed on professionalism. A questionnaire is given to students about the Institute of Mathematics and its Application (IMA) and the process of becoming a chartered mathematician. Another institution compiled this questionnaire on behalf of the IMA. Once students complete the questionnaire, they write a report about the IMA professional body that is assessed by the module coordinator.

18.2 Implementation

The assessments are very varied and broad, and it is unclear exactly how effective each assessment is in measuring students' work-related skills. We sought to evaluate this through a questionnaire to the second year undergraduate students who have taken the module. The questionnaire was designed to give both quantitative and qualitative data, which we evaluate separately below. First, students in both the first and second year were asked to consider which of the following work related attributes are deemed *important and useful* "in a modern undergraduate mathematics degree":

- Professional development
- Mathematical Modelling
- Problem Solving
- Workplace Preparation
- Introduction to Work Practices
- Teamwork
- Employer Engagement

This list was developed in discussion with other academics on the programme and with industrial partners. Students were asked to respond on a five point Likert scale ranging from 'of no importance [or usefulness]' to 'Extremely important [or useful]'. After rating the importance and usefulness of each attribute in a degree, the second year students from the *Business and Industrial Mathematics* module were asked to rate the effectiveness of each of the four assessments in the module at developing these attributes, again on a five point Likert scale.

We also asked the students to complete some open text boxes, giving their opinions on

- Strengths and weaknesses of the module
- Whether they would recommend the module to a friend
- What they would do differently in the module (if anything)
- Whether (and how) they had changed their professional development as a result of the module.

In total 27 students completed the importance/usefulness quantitative questionnaire (16 first years and 11 second years). The 11 second year students evaluated the four different assessments on the module against those attributes and eight of them filled out responses to the qualitative part.

18.3 Evaluation of the quantitative findings of the data analysis

Figure 18.1 shows the mean responses (with standard error bars) of the importance and usefulness of each attribute to a modern degree course. There are no significant differences between the responses to importance and usefulness, so, for the purposes of further analysis, we simply concentrate on importance. There are significant differences between the perceived importance of the attributes $(F(6,182) = 6.52, p < 0.001)$.

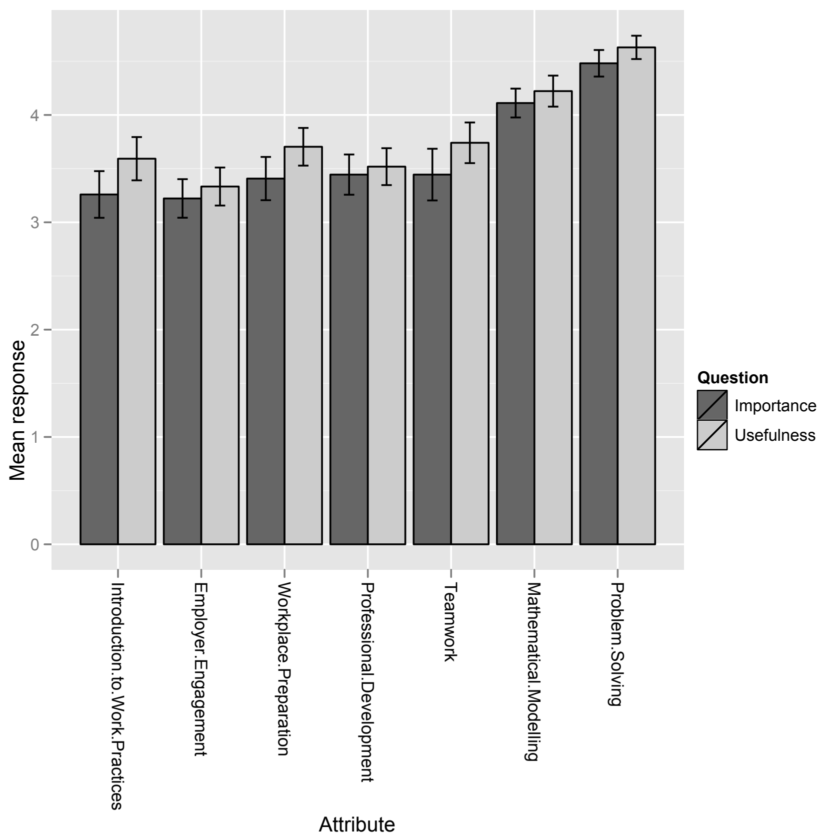

Fig. 18.1 Relative importance and usefulness of the work-related attributes

In particular, it is noticeable that students put the mathematical content (problem solving and mathematical modelling) as more important than professional attributes, such as professional development and introduction to workplace practices. Post-hoc t-tests (with Bonferroni corrections) show that problem solving is significantly more important than all attributes other than modelling and that modelling is significantly more important than employer engagement and introduction to workplace practices (all $ps < 0.05$).

We also found that there were no significant differences between the first year and second year views of these attributes, even though the second years had more experience and had taken the *Business and Industrial Mathematics* module, although the difference between the importance of employer engagement bordered significance ($t(25) = 2.018, p = 0.054$).

Given this pattern of perceived importance of the different attributes, we examined which assessments were seen as more effective at measuring these attributes (Figure 18.2).

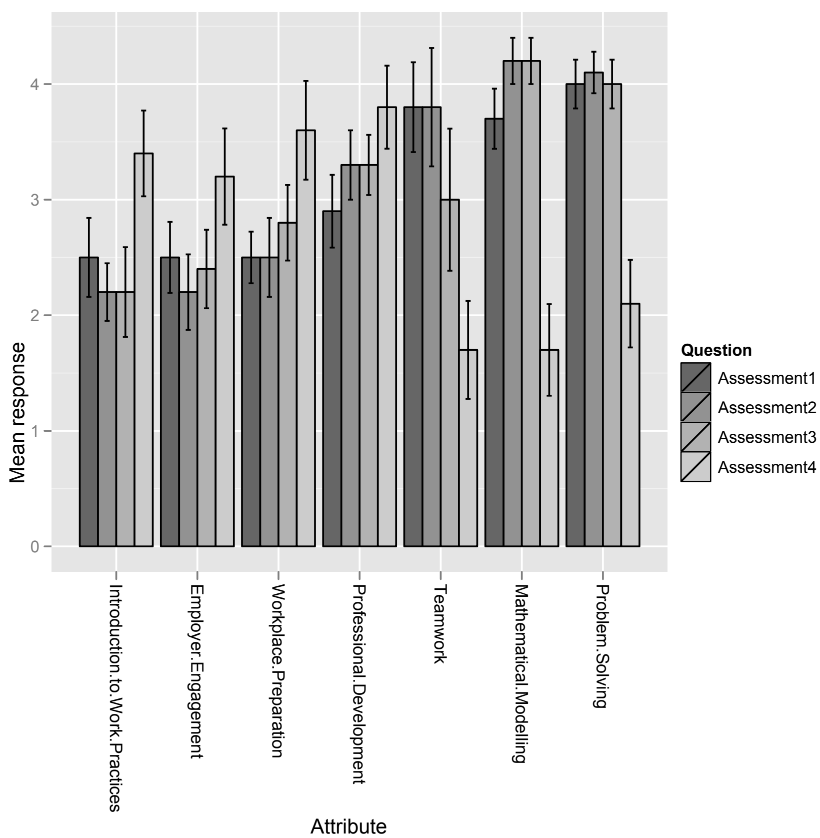

Fig. 18.2 Effectiveness of each assessment over attribute range

A cursory examination of the graph shows that assessment 4 (which focussed on professionalism) appears more effective at assessing the professional attributes of introducing workplace practices, employer engagement and workplace preparation than the other three, though given the sample sizes these differences were not significant. However, assessment 4 was significantly worse at measuring mathematical modelling and problem solving than the other three (all $ps < 0.001$) and worse than assessments 1 and 2 for measuring teamwork (all $p = 0.028$ for both).

There is also the general sense in the graph that students see the first three assessments as having similar patterns of effectiveness across each attribute and that, in general, they are better at assessing problem solving and modelling skills, than the work practice and employer engagement attributes. Again, with small sample sizes, not all of these reach significance, but pairwise t-tests with Bonferonni adjustment show that assessment 1 is seen as significantly more effective at measuring problem solving than work practices, employer engagement or workplace preparation. Assessment 2 is significantly more effective at measuring teamwork, modelling and problem solving than work practices or employer engagement and significantly more effective at measuring modelling and problem solving than workplace preparation. Assessment 3 is significantly more effective at measuring modelling and problem solving than work practices and employer engagement. Finally, assessment 4 is significantly more effective at measuring work practices, employer engagement, workplace preparation and professional development than teamwork or modelling, and significantly more effective at measuring professional development than problem solving (all $ps < 0.05$).

The pattern across all of our data appears to suggest that the skills the students see as more important (problem solving and mathematical modelling) are indeed those which are more effectively measured by three of the four assessments, and, vice versa, the skills seen as least important (work practices and employer engagement) are measured less effectively by those three assessments - though they are covered by the fourth.

18.4 Evaluation of the qualitative findings of the data analysis

The qualitative data analysis presents students' perceptions of the module's strengths and weakness, benefits and views on its assessment strategies. In the following evaluation, the symbol '(n)' after each comment refers to the n^{th} questionnaire sheet.

The data show that students believe that the *Business and Industrial Mathematics* module consolidates and improves their team building skills. It prepares and trains students to further develop their employability skills. The module's configuration encourages students to think about and plan for future mathematics related careers. It helps students to "learn how to work as a team and also how to apply maths skills to real life situations" (3). This is an ideal outcome of the course as students can go on to undertake mathematical as well as non-mathematical related jobs. Students also feel that the module "gets you thinking and perhaps planning for a future career" (7). The assignments' structure appears to help improve students' communication and team skills, such as report writing, keeping minutes and presentation skills. Students believe that the module also improves their mathematics skills. The students state that the course concepts were interesting to work with as these improve students' creativity and perception of mathematics as they learn "to use problem solving and intuition for the earlier assignments" (8). Furthermore, being part of a team improves students' organisational skills. Students report enjoying that this module is not exam based, as they believe such an assessment structure offers more flexibility. They also mentioned the ease with which help and interaction are obtained from the lecturers.

The weaknesses of the module consist of students' failure to understand the relevance of the module for their future career path, the perceived difficulty to work as a team, and their desire to see more research. Students felt that not all the team members pulled their weight for the success of the project in an equal manner and this leads to experiencing "difficulty to work with a group of people who didn't put in as much effort as the others" (5). Ultimately, this creates some difficulties in working together as a team. Students also expressed their desire to have more guidance in organising meetings or in taking meeting minutes. Some students struggled to see the connection between the module and its relevance for future jobs and one even said the module does not present a challenge.

When asked whether or not they would recommend the *Business and Industrial Mathematics* module to a friend, students' perspectives appeared to be divided into four clusters. The first group of students believed the module gave good insights into what mathematics is. It provides interesting insights into mathematics and it is conducive to creating and implementing different solutions paths to math problems because "it was fascinating to see different methods developing to solve the problem" (5). Moreover, the module aims to create links with industry employees. Overall, the module offers an enjoyable mathematical experience and provides a clear and better understanding of mathematics. The second group of students stated that the module was well designed and had fresh perspectives to assessment. The third group of students thought that the module has the ability to open one's horizons as "it also tells you the benefits of joining certain groups" (1). The last cluster of students stated that it helps students in improving their employability skills, such as communication, presentation or report writing.

If given the chance, students would alter the module slightly. They would welcome being given more independence in choosing their groups, would like to see more time invested in creating more enhanced professional projects, and would like to see changes within the assessment structure. Only one respondent believed that the course is perfectly structured.

The students seemed to believe that the course is highly motivational. It helped them in changing their views about the nature of mathematics and even furthered their desire to join the Institute of Mathematics and its Applications. The module also contributed to increasing students' self-confidence in their mathematical abilities and in the team abilities: "now I am more confident in working with other people" (2). It made them consider embarking on graduate studies in mathematics as well as in mathematics related careers. Overall, it made them feel more prepared.

18.5 Discussion, learning and impact

The picture from the quantitative data is, as it should be, of assessments that students perceive as being most effective in assessing precisely those attributes they see as most important (and most useful) in a modern degree course. However, they viewed the assessments quite differently - assessments 1, 2 and 3 all tended to elicit the same pattern of responses (that the more important the attribute, the more effective the measure), but assessment 4 tended to be more effective with the less important attributes.

However, given that the students' views tend to be that the more important attributes are more mathematical (such as problem solving and modelling) and the less important are the direct employment and workplace attributes (introducing workplace practices and employer engagement), it suggests that the balance is about right. It does call into question the extent to which employment related skills may be valued by students even in a module designed to emphasise mathematics in the workplace.

18.6 Further development and sustainability

The qualitative evaluation indicates a direction for future development. Difficulties associated with students' disengagement in working with others in teams need to be addressed. Comments indicate that greater help on how to perform work-related tasks such as writing reports, taking minutes and conducting meetings would be beneficial to students. The problems set to the students could be reconsidered, including increasing the level of difficulty, providing a research focus and further developing the work-related context.

Overall, the module can be deemed successful in that the evaluation demonstrates the assessments were effective in developing the most important and useful attributes in the eyes of the students.

References

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