

Mathematics Lecturers' Views of Examinations: Tensions and Possible Resolutions

Journal:	<i>Teaching Mathematics and Its Applications: International Journal of the IMA</i>
Manuscript ID:	TEAMAT-2014-015.R1
Manuscript Type:	Original Article (Section A)
Date Submitted by the Author:	26-Aug-2014
Complete List of Authors:	iannone, paola; University of East Anglia, School of Education and Lifelong Learning Simpson, Adrian; Durham University, School of Education
Keywords:	Assessment at university, lecturers's perceptions, closed book examinations

Teaching Mathematics and its Applications (2014) Page 1 of 13
doi:10.1093/imanum/drnxxx

Mathematics Lecturers' Views of Examinations: Tensions and Possible Resolutions

PAOLA IANNONE [†] AND ADRIAN SIMPSON [‡]

[Received on xxx; revised on xxx]

Abstract: If assessment drives learning and the closed book examination dominates the pattern of assessment for undergraduate mathematics (as it does in the UK), lecturers need to ensure that examinations reflect the learning they value. This paper uses a mixed method approach to explore lecturers' views of the closed book examination in relation to other assessment methods, their preferences for different types of methods and the extent to which they discriminate between stronger and weaker students. A survey of staff views confirms the dominance of closed book examinations, but an accompanying interview study shows hidden complexity to this view. In particular a tension between the potential and the reality of examinations is uncovered and suggestions are made for resolving that tension.

1. Introduction

It has been suggested that assessment is an indicator of what teachers value and thus students use the content and form of assessment to direct what and how they learn (van de Watering, Gjibels, Dochy and van der Rijt, 2008). In the UK, there has been a general push across the higher education sector towards diversifying how we assess (Dearing, 1997; Browne, 2010). However, such calls are often made without taking the requirements of the academic subject into account and some have argued that insufficient attention has been paid to the contrast in the nature of different disciplines when advice about assessment is given (Joughin, 2010). Moreover, despite the way in which assessment dominates the debate on learning and teaching in higher education, there have been few explorations of university lecturers' perceptions of assessment, its relation to what they value and what assessment methods they believe to be good indicators of ability in their academic subject.

This paper reports results from an exploratory study of UK mathematics lecturers' preferences of assessment methods and focuses particularly on their perceptions of the potential and drawbacks of the overwhelmingly dominant assessment method: the closed book examination.

2. Literature Background

While the general literature on students' perceptions of assessment methods is rich (see Struyven, Dochy and Janssens, 2005, for a review), the literature on lecturers' perceptions is limited. One of the few empirical studies that examined academics' perceptions of the function of assessment found that lecturers' perceptions of the value and role of assessment are linked to their beliefs about teaching, and in turn about learning (Samuelowicz and Bain, 2002). The study suggested that lecturers' views on the use of certain assessment methods can be read on a continuum between valuing knowledge reproduction to

[†]Corresponding author. Email: p.iannone@uea.ac.uk

[‡]Email: adrian.simpson@durham.ac.uk

2 of 13

valuing understanding and the construction of knowledge.

There has been a long debate about the nature of assessment in different disciplines. The modes of assessment used in different areas reflect the characteristics of the areas (Neumann, Parry and Becher, 2002) and even so-called *generic* skills can be viewed and assessed differently in different disciplines (Jones, 2009). Norton, Norton and Shannon's (2013) study showed that discipline can have an effect on both the extent to which lecturers feel their use of assessments matches desirable practice and how much they feel constrained in their choice of assessments, at least amongst those relatively new to university teaching. Thus it is important to take account of the source of the participants in a study to recognise the generalisability of the messages. Thus, while Samuelowicz and Bain's findings come from research with academics in a number of disciplines (architecture, nursing, physiology, physiotherapy and chemistry) it is not clear how the views expressed may adapt to other subjects.

In particular, amongst mathematicians in the UK, concern has been raised that the nature of the subject may require different methods from those which generalist educational research, national bodies or central university units may recommend for implementation across disciplines (LMS, 2010). What Iannone and Simpson (2011) describe as the 'assessment diet' for mathematics students in the UK is remarkably uniform across institutions. They found that in the vast majority of degree courses, written examinations account for well over half the summative assessment and is overwhelmingly the main contributor to the final degree classification. Of course, they also noted that examinations are rarely the sole form of assessment: most universities have some form of final year project and methods such as weekly homework sheets, presentations and computing projects are not uncommon, but the assessment of mathematics is heavily dominated by the closed book examination.

Little previous research has examined university lecturers' views of assessment practices in general, or closed book examinations in particular. Bergqvist (2012) did explore the factors which affect Swedish university mathematics teachers' construction of examination questions, noting four main components: the time they have to construct the examination, the degree of difficulty, the type of task and the content. However, Bergqvist's main focus is on the type of reasoning required by the examination, not on the lecturers' views of the assessment diet and the role of the examination within it.

Given the dominance of the closed book examination, there is a need to uncover the perceptions and preferences of the lecturers in their roles as assessors. In view of the very rich scholarly literature supporting innovations in the assessment of mathematics (such as Hirst and Biggs, 1968; Berry and Houston, 1995; Haines and Crouch, 2005) which appear not to have had a large impact on the pattern of assessment at universities, it is important to ask what lecturers' views of the closed book examination and its dominance are, which methods are perceived as most suited to assess mathematics ability and whether there are alternatives to closed book examinations they would like to use. This paper addressed these questions and investigates what has led to the current uniformity of assessment diet in the UK.

3. Methodology

Mathematics lecturers at two research intensive universities in the UK were recruited to take part in this study. The two institutions have an assessment diet which reflects the general pattern of research-intensive institutions in the UK: Assessment in all years is largely dominated by closed book examinations, though one university (called *Uni1* below) has a module assessed by a project in year 3 and the other (*Uni2*) has a similar module in year 2.

The study had two phases. In the first, all academic staff in the two departments were contacted to complete an online questionnaire on assessment preferences and views of assessment methods. This aimed to provide background context to the second phase consisting of focussed interviews with some

of the staff.

The first phase mirrored the approach taken in studies on students' perceptions of assessment (such as Gijbels and Dochy, 2006 and Iannone and Simpson, 2014) in using an adapted form of the Assessment Preferences Inventory (API) developed by Birenbaum (1994). The API asks participants to rate different forms of assessment according to the study's focus. The adapted API was based on eight different assessment methods which might be used or applicable to mathematics and which were adopted directly from Iannone and Simpson (2014). These were given with a short description, thus:

- **Multiple choice examination:** e.g. a test taken in an exam room, where for each question you have to select one response from five possible choices
- **Written examination with no support materials:**¹ e.g. a test taken in an exam room, with a separate booklet in which you write solutions, but where you are not allowed to use a calculator, books or any other support materials
- **Written examination with support materials:**² e.g. a test taken in an exam room, with a separate booklet in which you write solutions, but where you are allowed a copy of the standard textbook for the course
- **Weekly examples sheets:** e.g. a test which you complete in your own time over the course of a week, based on the material covered in the course over that week
- **Project coursework:** e.g. a piece of written work submitted in response to a question or problem, undertaken over the course of a number of weeks)
- **Project presentation:** e.g. an oral presentation of the results of a project, undertaken in response to a set question or problem, after working on the project for a number of weeks
- **Oral examination:** e.g. working on a mathematical problem on a chalkboard or piece of paper with a tutor present who can provide suggestions or check errors as you work on it
- **Dissertation:** e.g. a substantial piece of written work, on a set topic or problem, undertaken over the course of a long period, such as a term or two

The questionnaire asked participants to rate each of these assessment methods on the following two issues on a Likert scale from 1 (meaning 'hardly at all') to 5 (meaning 'almost exclusively'):

- Q1 To what extent would you want undergraduate mathematics students' achievements to be assessed by each of the following methods?
- Q2 For each of these assessment methods decide how good it is at distinguishing those who are good mathematicians from those who are poor mathematicians.

The response rate to the online questionnaire was 15% ($N = 14$) which is similar to the level achieved by a similar study with students (Iannone and Simpson, 2014), albeit with a smaller population. All the respondents were male, but we note here that only 12% of the population of mathematics lecturers across

¹This is referred to as 'closed book' in the subsequent analysis

²This is referred to as 'open book' in the subsequent analysis

4 of 13

the two institutions were female, so a significant gender imbalance was not unexpected nor unrepresentative of the population. Given the [small](#) size of the response and the intention of the questionnaire as simply providing context, the results of the questionnaires should be taken as an indication of tendency without any view to wider generalisation.

For the second phase, all lecturers who completed the questionnaire were invited to attend an interview about their views and perceptions of assessment of mathematics at university. Six lecturers who represented a range of responses to phase one were interviewed for the study, three from each institution.

Given the exploratory nature of the study, the sample was self-selecting: as it happens, the lecturers are all male (though this reflects the highly skewed gender balance in UK mathematics departments), five were educated in the UK and one in Ireland (which probably does not reflect the relatively wide range of national backgrounds of those teaching in the departments), with teaching experience ranging from few years to over 20 years. All were involved at the time of the study in teaching undergraduate mathematics. Four of the lecturers self-identified as pure mathematicians, one as an applied mathematician and one as a statistician. The participants were interviewed individually in sessions lasting between 30 and 50 minutes.

The interviews were semi-structured and open-ended. There were a set of core questions presented to all participants aimed at eliciting the participants' perception of assessment methods in undergraduate mathematics, with particular emphasis on their perceptions of what knowledge and skills are assessed through the summative assessment methods in use in their department. However, the questioning in general was contingent on the participants' responses, taking the form of a 'focussed conversation' in which participants could express their views and the interviewer could seek clarification and further depth to get an insight into their views on assessment. The interviews were audio taped and fully transcribed.

The analysis of the interviews followed the thematic networks approach (Attride-Stirling, 2001). An initial coding framework was devised by both authors independently to identify the range of conceptions present in each interview. This was compared and negotiated and, as more data was drawn in, the framework was developed through an inductive cycle of independent analysis, development, comparison and negotiation until a final form was agreed. [The interview excerpts in the analysis of the interview data were then chosen to explain, illustrate and represent the theme to which they refer.](#) While other themes emerged (for example, in relation to notions of fairness) this paper focusses on the closed book examination, though different assessment methods are explored where they have been mentioned in relation to the closed book examination.

4. Results

Figure 1 shows the mean responses (with standard error bars) for [the questionnaire item on assessment discrimination: that is, how well the assessment method distinguishes between students on the basis of ability in the view of the respondents.](#) Due to the size of the standard errors of the means ([a consequence of the relatively small sample size](#)), it is hard to clearly identify a simple hierarchy of mean responses which are each statistically significantly different. However, the lecturers appear to see example sheets and multiple choice tests as less discriminating between good and poor mathematicians than closed book, dissertations, open book and oral exams (Bonferroni adjusted t -tests, all $ps < 0.05$). Closed book examinations were selected as the most discriminating or second most discriminating of the assessment methods by 79% of the participants.

Figure 2 shows the mean responses (with standard error bars) for assessment preference. The lecturers' preferences for assessment tended to follow existing practice, with closed book exams, disserta-

MATHEMATICS LECTURERS' VIEWS OF EXAMINATIONS

5 of 13

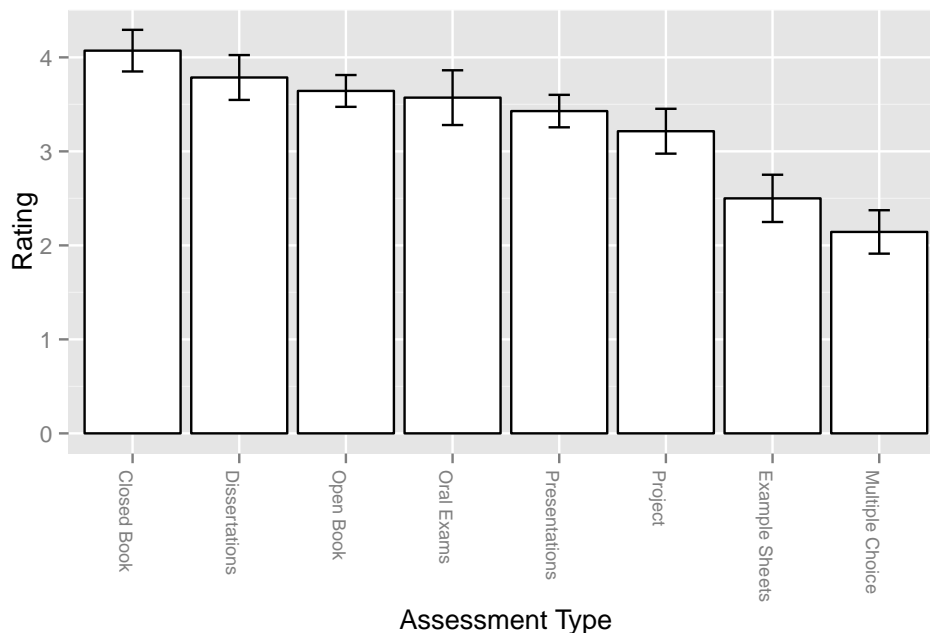


FIG. 1. Lecturers' Views of Assessment Discrimination

tions, projects and presentations as the most preferred and multiple choice tests the least. Closed book examination was selected by 86% of the respondents as their most preferred of the assessment methods.

The findings from the questionnaire illustrated in Figure 1 and 2 suggest that the closed book examination, as well as dominating practice, is one of the strong preferences for assessment method in the eyes of the lecturers and is something they see as discriminating well between stronger and weaker mathematicians. One interpretation is that the lecturer's simply have a relatively traditional view of assessment in their subject and value the status quo, but the second phase of the study allowed us to explore whether or not this was the case by focusing on the closed book examination and the lecturers' views of why these are so dominant.

In one sense, the lecturers' responses fit well with the results of phase one of the study: the lecturers appeared to recognise that the closed book examinations have potential to assess some of the dimensions they value: understanding, imagination, creating new connections etc.

Depends what the exam is, depends what the question is testing ... it usually means that they [*the students*] can think on their feet ... it probably means that they have done quite a few similar questions beforehand, so they've done a lot of preparation. It probably means that they are reasonably good at Mathematics. (Mark)³

What you'd hope is that they [*students who score well on closed book exams*] would have a very good understanding of the material that they haven't just engaged at a superficial

³Lecturers' responses are tagged with pseudonyms. Those with initial 'P' are from Uni1 and those with initial 'M' are from Uni2

6 of 13

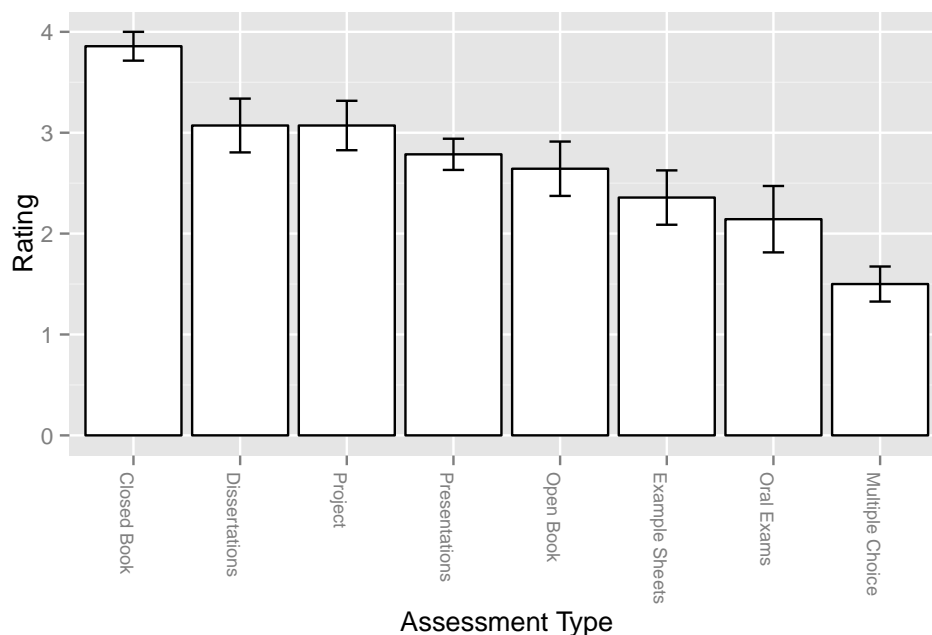


FIG. 2. Lecturers' Preference for Assessment Method

level, they really understand it, they see the problem, they understand what to do and they produce the solution. I think really the people who are getting the 95% most of them really are probably like that. (Paul)

However, the questionnaire does not reveal any nuance in lecturers' views of closed book examinations. While a naive view of the summaries in figures 1 and 2 may be of conservatism, in the interviews, the lecturers reveal a more complex context to the apparent preference for closed book examination.

For example, the strength of examinations may be their lack of the weaknesses which trouble lecturers' about other methods, such as the difficulty of ensuring marks reflect a student's own work or understanding:

I think there are logistic problems and I think that's possibly the reason why [*the university no longer uses coursework as summative*] . . . , because I know other universities have this problem and in [*another university*] we had this problem and possibly it's true here, that there's no guarantee that what you're marking is actually the student's work and that's true whether it's formative or summative, but if it's summative then it matters more because if it's formative then the student is really penalising themselves. (Peter)

Moreover, despite the generally positive view of closed book examinations in the questionnaire and, superficially, in the interviews, all of participants noted that the current reality, for them, is of examinations that fail to fulfil their promise.

An exam can tell you how well a student understands material if you're willing to ask

1
2
3
4
5
6
7
8
9
10
11 questions that require the demonstration of that understanding. But a lot of the time I think
12 that we don't use questions of that kind. (Patrick)

13
14 So there are at least two styles of written exam which I can identify - those that are com-
15 petency testing and those which are looking deeper and trying to see whether the student
16 has some imagination, some ability to connect things that nobody's shown them were con-
17 nected before. [...] a standard written exam, [...] to be honest is nowadays more or less
18 totally a competence type exam. (Peter)

19
20 There is an indication here that some lectures think that, while examinations in the past may have
21 been a more balanced assessment of abilities, they are now skewed heavily towards memorisation and
22 reproduction. Moreover, some of the lecturers believe that the cause of this shift lies in the concerns that
23 otherwise weaker students would be failed outright:

24
25 I think that most of us would accept ... our assessment process has become rather geared
26 to computation because that's easier to assess the output of an examination and also easier
27 probably to avoid disaster with weaker students. (Paul)

28
29 We're worried about the effect ... [*having more complex questions that test understanding*]
30 ... has on the weaker students, because they can't cope with those questions. (Patrick)

31
32 All of the participants' responses contained the same issue in some form: a sense of written exami-
33 nations having become, despite the potential, skewed towards memory and routine tests of competence.
34 The rationale given for the shift to competence testing in exams was not always simply that the lecturers
35 cannot be allowed to fail too many weaker students, but that in exam questions which test understand-
36 ing, weaker students tend to score close to zero. In more conceptual exam questions, small flaws in
37 understanding can multiply into an inability to complete the question at all.

38
39 ... the temptation would be to make the questions fairly difficult and might end up with a
40 distribution where good students have produced something and the weaker students might
41 have very little to fall back on. (Mark)

42
43 Maybe this is wrong, but I would feel in an open book exam, it seems perverse to ask for
44 the definition of something and they can just turn to that page and write it and copy it out.
45 And, since, well, for our weaker students, they essentially pass the [*closed book*] exams on
46 the basis of being able to do things like that. What are you going to ask them to replace
that? (Matthew)

47
48 The participants suggest that the consequence of this is that written examinations no longer differ-
49 entiate between students on the basis of the kinds of mathematical ability which many of the lecturers
50 value. Instead, they are seen to reward effort, diligence and memory and this impacts on how students
51 prepare for exams and how they approach learning material:

52
53 ... so with closed book exams and the sorts of questions we've asked, I think if you have a
54 good memory you're half way there and literally half way of the marks. What else? In fact,
55 on the whole, in order to get a good mark even on an exam, if you have been conscientious
56 and you've done all the coursework and you've revised and you've done questions from
57 past papers and so on, you will do well ... I think anyone who has actually just put the work
58 in will do well in exams. They don't actually need to be that talented. (Matthew)

1
2
3
4
5
6
7
8
9 8 of 13

10
11 ... [students have] the idea that you've just got to learn this, this, this and this and then
12 you have an exam and then you might just as well forget it, because you're not going to be
13 examined again. (Peter)

14
15 The analysis suggests that the comments from the lecturers are a manifestation of a tension: The
16 lecturers appear to want to assess understanding and creativity – which they feel the written examination
17 is capable of doing – but they seem constrained by a requirement to ensure that weaker students still
18 achieve. Yorke (2011) notes a tension within higher education more generally between “retention and
19 completion (with their implications for institutional funding) and ... the need for academics to uphold
20 standards” (p. 258). This concern in the context of mathematics may also relate to the tendency of
21 mathematics to have a far wider mark distribution than other subjects being coupled with the need to
22 map that wider range onto a similar set of degree classifications without serious imbalances (Bridges et
23 al., 1999)

24 Thus the lecturers in this sample feel they 'fall back' on questions which test memory and com-
25 putation. This, paired with the ease of marking of memory and computational questions, seems to
26 have driven the written examination to a test of reproduction and routine applications of techniques. In
27 general, they are not - the lecturers maintain - a test of mathematical understanding.

28 This tension between wanting to test qualities they value (such as understanding or imagination) but
29 being pushed into rewarding less valued abilities (like memory and diligence) was apparent in all of our
30 interviews. However, when the lecturers were asked specifically about assessing understanding, ways
31 of relieving this competence-understanding tension emerged.

32 As noted earlier, the written examination may be dominant in the UK mathematics degree, but there
33 is some variation in the assessment diet. Most institutions have some form of project, often in the final
34 year and often for a relatively large portion of the year's marks. Both Uni1 and Uni2 had these types of
35 projects and these were seen as a mechanism for assessing understanding:

36
37 We don't really test their imagination [with closed book exams], or ability to apply mathe-
38 matics unless they're doing a project. (Michael)

39
40 In particular, the close interaction between the lecturers and the students, the individual nature of
41 the assessment and the frequency of contact mean that project supervision appears to give lecturers a
42 mechanism for judging the abilities they value:

43 ... challenge a student and then when the student comes back to you after thinking about
44 it for a while, they say I tried this and it didn't work and I can't think of what else to do,
45 at that point you can say well did you try this and they can go away and try that. So you
46 can assess how good they are, or how capable they are at thinking of ways for themselves
47 simply by talking to a student, for a reasonable amount of time. (Paul)

48
49 Moreover, projects (and their accompanying presentations) are not just perceived to be good forms
50 of assessing mathematical abilities which the lecturers value, but may also fulfil the role of helping
51 mathematics students developing employability skills in a degree course where there may be fewer
52 opportunities to develop such skills.

53
54 One of the things that's very odd about the system here, [...] It's very odd to have an as-
55 sessment system that is so unrelated to the needs of people when they go into employment,
56 'cos writing exams is completely unlike anything they're going to be asked to do. A viva
57 at least has the merit that it's similar to talking to the boss and trying to explain, yeah? A
58
59
60

presentation has a similar strength, presenting to the team, or a wider part within a company, or to a client and being able to write reports is one of the most valuable things that any employee can have, being able to write well. So we use an assessment method [*written examination*] that isn't helpful. (Patrick)

However, the project was not the only way that lecturers had of relieving the tension between wanting to assess understanding and having to assess competence. One other method emerged repeatedly from the interviews, despite playing no role in undergraduate assessment in mathematics in the UK (*even though it is common in many parts of Europe, De Vita and Case, 2003*). Most of the lecturers suggested a form of oral examination:

I would talk to them [*the students*], ... when you have one to one with a student you can very rapidly find out whether they know anything, or whether they can produce something from inside themselves or whether every time you have to say: 'this is what we do next'. (Peter)

and

I mean I think that what would be very good for the students and also would tell us a lot more about what they know would be to do oral. [...] I think it would be good because from my experience of seeing students in one to one you can see very quickly what they understand and what they don't, which is good for them to learn to express themselves, which they don't. They go out into the world, and I think most of them can't talk. (Matthew)

When lecturers were asked why there were no oral examinations they noted concerns with the lack of familiarity students have with this assessment method, quality assurance and moderation and the high demands that this assessment would put on staff time.

... but I think, I mean the ideal would be just to do one to one, or one to small number coaching so that you would actually really get to know the students individually and [*some places*] have the resources to be able to do that and I think that that is a great benefit of their system. But I don't think that [*our current resources allow us to*] ... it makes it more on a human scale rather than on an industrial scale. (Paul)

I don't know whether [*introducing oral exams*] would genuinely really be difficult, but I think that thing that holds people back is the impression that QAA would make it difficult to somehow audit it. (Matthew)

5. Discussion and Concluding Remarks

To some extent, our study confirms some aspects of the work of Samuelowicz and Bain (2002), though situated specifically in mathematics. Our participants discuss their orientations towards the use of assessment methods in relation to what type of knowledge the assessment method aims to assess and to their beliefs about the importance of certain types of knowledge over others. This is exemplified in the way our participants indicate their wish to assess mathematical understanding, which they believe to be at the core of mathematics learning, and regret having to assess less important aspects like memory and procedures instead. In our study, however, the lecturers describe at great length the potential and the

10 of 13

problems of the overwhelmingly dominant summative assessment method: the closed book examination. The questionnaire notes their preference for its use and their view of it as good at discriminating stronger from weaker students, but failed to uncover a layer of subtlety which came from the interviews.

Of course, this was an exploratory study based on a small and self-selecting sample of lecturers at two research intensive institutions. The interviews might reflect views of those who, within such environments, naturally associate themselves more with teaching and assessment – after all, the interviewees gave up their time for an discussion about assessment. Similarly, views may differ at institutions which have a wider range of assessment practices, have different aims or teach students from different backgrounds.

However, the lecturers in this study make a clear distinction between the potential of closed book examinations to assess competence (which they describe as the ability to reproduce seen definitions and procedures and apply algorithms in familiar situations) and the potential to assess understanding (characterised by the lecturers as the ability to tackle unseen problems or apply familiar procedures in new situations). They all appeared to express a tension between these which most recently tended to skew examinations towards assessments of memory and routine applications (or what Boesen, Lithner and Palm, 2010, would call “imitative reasoning”).

While we noted at the beginning of this paper that assessment is often taken to be an indicator of what teachers value and which thus drives students’ learning, the findings from this exploratory study may indicate that, in mathematics, lecturers have unwittingly found themselves sending out the wrong signals through their assessments, because of this apparent tension. It is clear that mathematicians feel that their subject has a particular nature that means its pattern of assessment may need to be different from the types of assessment generalist educational research, national bodies and institutional central units are recommending. But equally, they acknowledge that the dominant assessment method - the closed book examination - as currently implemented is not testing the sorts of abilities they value. Instead it may be rewarding memory and diligence and so driving student learning in the opposite direction to that they intend.

Some of the lecturers noted that there are forms of assessment which may better assess the abilities they value: projects and oral examinations. Both of these have drawbacks, however: the former is felt to require considerable resources and they latter raises concerns for the lecturers about quality assurance. Moreover, the recent survey of assessment practices in the UK mathematics departments also noted some institutions in which there was a move away from alternative assessment methods and towards still more written examinations because of concerns about plagiarism and collusion (Iannone and Simpson, 2012).

However, lecturers appear to acknowledge that the closed book examination’s emphasis on competency and memory need not be the case. They are seen as having the potential to assess understanding and creativity and were judges as the best of the forms of assessment in phase one of our study by nearly 90% of the respondents. The problem, then, may not lie with the form of assessment itself. Instead, the interview participants suggested cause is the need to enable weaker students to pass in a subject which tends to have a wide spread of marks, but which needs to map those on to a relatively standard spread of degree classifications. Some of these views resonate with those expressed by the university teachers interviewed by Bergqvist (2012). She noted those setting examinations feel they are influenced by what she called a “degree of difficulty” factor: needing to set tasks which do not lead to too high a failure rate. It also fits with Norton et al.’s (2013) finding that relatively new lecturers in ‘hard’ subjects feel more constrained in their assessment practices than lectures in ‘soft’ subjects.

Shay (2008) calls for a need to centre assessment practices on disciplinary forms of knowledge, putting the nature of the discipline in the foreground in the design of assessment practices. Thus the issue

may be to look at the design of written examinations and see if questions can be designed to differentiate on the basis of abilities mathematicians value, without leaving weaker students with discouragingly low marks. One might, for example, look to questions that test comprehension of proofs rather than reproduction or construction (Mejia-Ramos, Fuller, Weber, Rhoads and Samkoff, 2012) or consider the wide range of different examination questions and dimensions on which they can vary discussed in Griffiths and McLone (1984). Such approaches may enable us to relieve the understanding-competence tension, while maintaining the pattern of assessment peculiar to mathematics.

Acknowledgement

We would like to thank the Maths, Stats & OR Network (MSOR) of the Higher Education Academy in the UK for funding the research reported in this paper.

REFERENCES

- ATTRIDE-STIRLING, J. (2001). Thematic networks: an analytic tool for qualitative research. *Qualitative Research*, 1(3), 385–405.
- BERRY, J. & HOUSTON, K. (1995). Students using posters as a means of communication and assessment. *Educational Studies in Mathematics*, 29, 21–27.
- BERGQVIST, E. (2012). University mathematics teachers' views on the required reasoning in calculus exams. *The Mathematics Enthusiast*, 9(3), 371–408.
- BIRENBAUM, M. (1994). Toward adaptive assessment? the student's angle. *Studies in Educational Evaluation*, 20(2), 239–255.
- BOESEN, J., LITHNER, J., & PALM, T. (2010). The relation between types of assessment tasks and the mathematical reasoning students use. *Educational Studies in Mathematics*, 75(1), 89–105.
- BRIDGES, P., BOURDILLON, B., COLLYMORE, D., COOPER, A., FOX, W., HAINES, C., TURNER, D., WOOLF, H. & YORKE, M. (1999). Discipline-related marking behaviour using percentages: a potential cause of inequity in assessment. *Assessment & Evaluation in Higher Education*, 24(3), 285–300.
- BROWNE, J. (2010). *Securing a Sustainable Future for Higher Education*. London: HMSO.
- DEARING, R. (1997). *Higher Education in the Learning Society*. National Committee of Enquiry in Higher Education. London: HMSO.
- DE VITA, G. & CASE, P. (2003). Rethinking the internationalisation agenda in UK higher education. *Journal of Further and Higher Education*. 27(4), 383-398.
- GIJBELS, D., & DOCHY, F. (2006). Students' assessment preferences and approaches to learning: Can formative assessment make a difference?. *Educational Studies*, 32(4), 399–409.
- GRIFFITHS, H.B. & MCLONE, R. (1984). A critical analysis of university examinations in mathematics, Part II: A problem of evaluation. *Educational Studies in Mathematics*, 15(3), 423–442.
- HAINES, C. & CROUCH, R. (2005). Applying mathematics: making multiple-choice questions work. *Teaching Mathematics and its Applications*, 24(2–3), 107–113.
- HIRST, K. & BIGGS, N. (1968) Undergraduate projects in mathematics. *Educational Studies in Mathematics*, 1(3), 252–261.
- IANNONE, P. & SIMPSON, A. (2011). The summative assessment diet: how we assess in mathematics degrees. *Teaching Mathematics and its Applications*, 30(4), 186–196.
- IANNONE, P. & SIMPSON, A. (2012). *Mapping University Mathematics Assessment Practices*. Norwich, UK: University of East Anglia.
- IANNONE, P. & SIMPSON, A. (2014). Students' preferences in undergraduate mathematics assessment. *Studies in Higher Education*, DOI:10.1080/03075079.2013.858683.
- JOUGHIN, G. (2010). The hidden curriculum revisited: a critical review of research into the influence of summative

12 of 13

- assessment on learning, *Assessment & Evaluation in Higher Education*, 35(3), 335–345.
- JONES, A. (2009). Redisciplining generic attributes: the disciplinary context in focus, *Studies in Higher Education*, 34(1), 85–100.
- LMS (2010). *Mathematics degrees, their teaching and assessment*. London: London Mathematical Society Position Paper.
- MEJIA-RAMOS, J. P., FULLER, E., WEBER, K., RHOADS, K., & SAMKOFF, A. (2012). An assessment model for proof comprehension in undergraduate mathematics. *Educational Studies in Mathematics*, 79(1), 3–18.
- NEUMANN, R., PARRY S. & BECHER, T. (2002). Teaching and learning in their disciplinary contexts: A conceptual analysis. *Studies in Higher Education*, 27(4), 405–417.
- NORTON, L., NORTON, B., & SHANNON, L. (2013). Revitalising assessment design: what is holding new lecturers back? *Higher Education*, 66(2), 233–251.
- SAMUELOWICZ, K. & BAINE, J. D. (2002). Identifying academics orientations to assessment practice. *Higher Education*, 43(2), 173–21.
- SHAY, S. (2008). Beyond social constructivist perspectives on assessment: the centring of knowledge. *Teaching in Higher Education*, 13(5), 595–605.
- STRUYVEN, K., DOCHY F., & JANSSENS S. (2005). Students' perceptions about evaluation and assessment in higher education: a review. *Assessment and Evaluation in Higher Education*, 30(4), 331–347.
- VAN DE WATERING, G., GIJBELS, D., DOCHY, F & VAN DER RIJST J. (2008). Students' assessment preferences, perceptions of assessment and their relationships to study results. *Higher Education*, 56, 645–658.
- YORKE, M. (2011). Summative assessment: dealing with the 'measurement fallacy'. *Studies in Higher Education*, 36(3), 251–273.

Note on Contributors

Paola Iannone is senior lecturer in educational research in the School of Education and Lifelong Learning in the University of East Anglia. Her research interest is teaching and learning mathematics at university level, with particular focus on assessment and proof and proof production.

University of East Anglia
School of Education and Lifelong Learning
Norwich, NR4 7TJ
Tel: (01603) 591007, p.iannone@uea.ac.uk

Adrian Simpson is reader in mathematics education in the School of Education at Durham University and is also the Principal of Josephine Butler College. His research has primarily focused on students' thinking across the transition from school to university mathematics, the transition to independent graduate study and mathematical logic and rationality.

Durham University
School of Education
Durham, DH1 3HP
Tel: (0191) 3347261, adrian.simpson@durham.ac.uk