



UCC

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Coláiste na hOllscoile Corcaigh

Fheabhsú Cáilíochta
Quality Enhancement

SCHOOL OF
MATHEMATICAL SCIENCES



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GOOD PRACTICE CASE-STUDY
TRANSITIONING TO E-ASSESSMENT IN MATHEMATICS
EDUCATION (TEAME)

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Case Study Summary on a Page

Title: Transitioning to e-Assessment in Mathematics Education (TEAME)

Subject area: Mathematical Sciences

Initiative's current stage: established

Target groups: Students in large 'service' mathematics and statistics courses.

Staff involved: Tom Carroll, Kieran Mulchrone, Stephen Wills (UCC) & Áine Ní Shé, Julie Crowley, Deirdre Casey (MTU)

Summary of Case Study: This initiative dates to around 2014 at which time mathematics staff at Cork Institute of Technology (now Munster Technological University - MTU) were using the Numbas platform for in-class e-assessment of student learning. Having become aware of this relatively new platform, we (Tom Carroll and Kieran Mulchrone) set about leveraging this platform's potential to put in place regular formative e-assessment for students in some of our large mathematics classes, in particular *MA1001/MA1002 Calculus for Science I and II*, for which such regular individual student feedback is completely impractical.

Together with colleagues at what was then CIT, including Áine Ní Shé, Julie Crowley and Deirdre Casey, we successfully applied for funding to develop this project under the National Forum's *Building Digital Capacity 2014* call. This funding was used to develop the concept at a local level, to produce content for use at both UCC and CIT and roll this out across modules at both institutions, and to disseminate our best practice and findings nationally and internationally both through seminars and workshops at interested institutions and through a dedicated website www.teame.ie.

Numbas continues to be used across a range of modules in both UCC and MTU through a growing number of engaged colleagues. In UCC, Numbas now forms an integral part of the modules *MA1059 Calculus*, *MA1011 Mathematical Methods 1* and *MS1002 Calculus*, *MA1012 Mathematical Methods II*, *MA2051 Mathematical Analysis I*, *MA3051 Mathematical Analysis II*, *MA4403 Financial Mathematics* and *MS3019 Financial Mathematics*, as well as the original modules MA1001 and MA1002. Many hundreds, if not thousands, of students at both institutions benefit from the immediate feedback on their work enabled by Numbas and the targeted Numbas content that is being constantly created and updated by our Teame.

Section One: Origins and Overview

In May 2014, we attended a National Forum for Teaching and Learning Seminar Series event that was organised by the Department of Mathematics at the then Cork Institute of Technology (CIT/MTU). The seminar focused on the potential of Numbas-based e-assessment in mathematics. Numbas is a free, flexible, e-assessment platform, developed and maintained at the University of Newcastle, and facilitates the construction of localised formative e-assessment. The difficulty with providing students in large mathematics and statistics classes with regular, prompt feedback on their work had long been recognised in the School of Mathematical Sciences at UCC and generally (see [1] and [2]). Marking hundreds of assignments by hand is impractical and a poor use of time. On the other hand, there is little for a student to learn from a multiple choice exercise with no feedback. As a consequence, we were enthusiastic to learn of the Numbas platform and how it was being used in CIT.

When the National Forum for Teaching and Learning subsequently put out a call for proposals under the *Building Digital Capacity 2014* banner, we applied for funding to develop Numbas content on a collaborative basis between UCC and CIT. With the support of Office of the Vice-President for Teaching and Learning at UCC, and the then Vice-President Professor John O'Halloran, we successfully applied for funding under this call for the project *Transitioning to e-Assessment in Mathematics Education* (€58,162). The funded project ran from December 2014 to December 2016.



The TEAME at the final presentation to the National Forum and International Panel at the Royal Irish Academy in Dublin, November 2016. From left to right: Deirdre Casey (MTU), Vivienne Terhurst (Project Manager), Julie Crowley (MTU), Kieran Mulchrone (UCC), Áine Ní Shé (MTU), Tom Carroll (UCC).

Section Two: Purpose

The context for this initiative is the ever evolving setting of third level assessment, in particular assessment in mathematics and statistics, in the context of large class teaching. E-assessment in mathematics presents particular challenges due to unavoidable specialised notation. Our motivation was to provide a better service to our students by providing timely feedback on their work thereby enabling learners to judge their progress in real time. The greatest barriers to providing timely feedback lies with large class size. We were particularly cognisant of the fact that these tended to be first year classes in the main, classes of students who might already be struggling with the transition from a mainly cosseted second level school system to an unfamiliar environment and system, and who were faced with impersonal classes of hundreds of students. The need to provide these students with timely feedback on their progress was clear, but the mechanism to achieve this was not.

Precursors to Numbas tended to be static, inflexible and generally limited in scope. The greatest barriers, perhaps, lay at the student's end who had the challenge of inputting answers in mathematical notation often in a form different from what might be used in class (as a simple example, x^{**3} for x^3). The compromises inherent in these early systems very much limited their effectiveness. The Numbas platform, which is under constant development by the team led by Christian Perfect at the University of Newcastle, overcame these difficulties so that, effectively for the first time, it became possible to realise e-assessment for large mathematics and statistics courses at UCC and CIT. The Numbas system facilitates:

- the use of mathematical notation in question creation using the well-known LaTeX typesetting programme first created by Donald Knuth;
- randomly generated variables so that each student gets a different question (or so that a student can redo a question with different numbers). The generated values can be constrained so that degenerate or awkward cases don't arise - (as a simple example, if a quadratic equation $ax^2+bx+c=0$ is to be solved for x with a , b and c as variables, it can be specified that b^2-4ac is positive to avoid complex solutions);
- students can be required to enter their answer in a particular form: as a simple example, if a student learning about powers is asked to write 2^3x5^2 as a single number then it can be arranged that 200 is marked as correct but that 2^3x5^2 or $8x25$ are not;
- each question can have an 'advice' section that a student may access if she wishes to see where she may have gone wrong: this advice will use the particular values of the variables in the current implementation of the question and, if well-considered, will point the student in the direction of the most common errors relevant to the topic in question. The student can subsequently work through a similar version of the same question, now with an improved understanding of the topic;
- adaptive marking, so that a student's incorrect answer to a previous question part can be carried forward to the next part and credit given if the student's follow through work is correct.

Our goal, then, was to develop Numbas resources that would be specific to target modules and then to put these into practice in the curriculum, revising module assessment specifications as appropriate.

Section Three: Design

In selecting the modules that would feature in the design phase of the Numbas roll-out, we chose those modules where the need was greatest and the impact would be immediate and substantial. In CIT these were certain mathematics and statistics modules for business students. At UCC we chose MA1001 and MA1002, each of which has more than 500 students from a range of first science programmes. It soon became clear that there were differences between the teaching paradigms at UCC and CIT that would fundamentally influence the design and implementation of any e-assessment. While the cohort of a CIT module taken all together might be substantial in number, in practice students were taught in small groups. This meant that Numbas e-assessment at CIT could be integrated into some of the tutorial/lecture times and run under the supervision of the lecturer. Any issues the student might have with the technology - how to get started, how to enter a certain expression - could be dealt with on the spot. At UCC, however, lectures are to the entire cohort and even tutorial groups are large. Computer lab space and time is at a premium and militates against *supervised* student engagement with Numbas. These differential issues gave rise to particular obstacles for Numbas implementation at UCC that could not be entirely overcome - there is no perfect substitute for face-to-face, real time interaction with students. The issue was mitigated by recording detailed videos for students of how to take a Numbas 'exam' and how to input various types of mathematical expressions in Numbas format. These videos were subsequently made available on the relevant module page on UCC's VLE.

Notwithstanding these different modes of teaching, our first task was to design relevant student activities and implement these in Numbas. The former requires expert content knowledge as well as an understanding of which material students find most challenging. Even basic mathematical skills best internalised at second level may be absent as the student transitions to third level - the introduction of *Project Maths* (a revised second level mathematics syllabus) was an additional complication in this regard. The latter is also non-trivial since, even if Numbas exercises are relatively intuitive for students to use, implementing these exercises in Numbas requires expertise in LaTeX, JME and a certain familiarity with coding. With content in place, we were ready to bring Numbas to the classroom.

Section Four: Implementation

The initial integration of Numbas e-assessment into UCC's MA1001 did not work seamlessly because of an incompatibility with the then UCC VLE - *Blackboard*, which transpired to be unreliable when it came to recording students' grades. A Numbas 'exam' was uploaded to Blackboard (to the VLE in general) as a SCORM package which then runned internally in Blackboard and produced a mark as the student works through the exercises in the 'exam'. This mark is recorded in the gradebook for the relevant module. This recording, however, was persistently unreliable - grades recorded as zero, or no grade recorded, or grades overwritten if the student re-attempted the 'exam'. Moreover, there was no identifiable pattern to these recording errors - a student's grade might be recorded perfectly for some weeks in a row only for a recording error to occur under apparently the same conditions (laptop/PC, browser, etc.). These difficulties militated against one of the main goals of the project which was to make better use of staff time by automating what would otherwise be a repetitive and

time-consuming task while at the same time providing students with immediate feedback on their work.

To solve this problem, we used project funds to purchase a standalone server on which Kieran installed the VLE *Moodle*. Moodle offered the possibility of reviewing all previous attempts by a student in case their final mark for that assessment had been overwritten or otherwise recorded incorrectly. Setting up Moodle on the server was a significant technical challenge and a time-consuming one - once set up, though, it solved (at least it greatly reduced) our recording problem and enabled the project to proceed.

On the other hand, the integration of Numbas assessments into modules at CIT proceeded well. Numbas pioneers, such as Julie Crowley, had already forged ahead even before the National Forum award in 2014. This award then facilitated an expansion of the use of Numbas in CIT/MTU into several other modules and its adoption by a wider cohort of the staff there.

Together, the TEAME created many Numbas-based assessments or worksheets on various topics relevant to first year mathematics and statistics. These were hosted on a dedicated website, www.teame.ie, in order to make our work more visible and to disseminate our learnings in this area. These worksheets were hosted on the website as stand-alone worksheets - and as SCORM - so that they could be used directly from the website itself. At around this time, we employed the services of a Project Manager, Vivienne Terhorst, who was instrumental in our dissemination efforts. We created an Implementation Guide to assist academics at other institutions who wished to integrate Numbas into the own modules, making this guide available both as a printed copy and on our website. We brought progress on our project to a wider audience through a dedicated twitter account.

Section Five: Review/Evaluate

This initiative has had significant impact at UCC, at MTU and internationally. Rapid, sustained expansion of the use of Numbas at UCC and MTU (CIT) followed. Currently, 800 students or more take Numbas assessments at UCC, 600 at MTU, each year. Since 2015/16, 400-500 general science students in MA1001 and MA1002 engage with Numbas-based assessments run by the lecturer, Purnima Chaudhry, assisted by Kieran and Tom, as an integral part of these modules. Stephen Wills (Mathematics, UCC) has become an expert user of Numbas, incorporating a weekly element of continuous assessment into the modules MA1011 and MA1012, both of which are taught to around 150 first-year Engineering and other students each year. The assessments are delivered via the institutional VLE *Canvas* and provide immediate, automated feedback to students. Stephen writes “On beginning to use it in 2015/16 it quickly became apparent that it could be used for a dual purpose: weekly assessed homework, as a means of ensuring constant engagement in the module throughout the semester, but also by providing practice problems with detailed solutions, which in particular can assist with weaker students, e.g. those who arrive into UCC with gaps in their knowledge from second-level”. Stephen has subsequently made use of the system for students in the BSc degrees in Mathematical Sciences / Financial Mathematics and Actuarial Sciences / Joint Honours Mathematics and Physics (in the modules MA2051 and MA3051), and in the BComm and BA Mathematical Sciences degrees (MA4403/MS3019). Tom Carroll has introduced Numbas-based assessments to his first year calculus course MA1059, Kieran Mulchrone to his applied mathematics course AM2021. The initial implementation of Numbas at CIT saw the introduction of computer-based assessment in a range of first year mathematics and statistics modules, with a focus on first year Business students, and has now expanded both in terms of the modules involved and the lecturers involved. This was evident at a *Digiteach e-assessment* Workshop organised by Julie Crowley (CIT) in May 2019. Feedback from students has also

been positive: as an exemplar, quotes from module evaluations for MA1059 Calculus 2018/19 show that students value these online assessments for strengthening their problem-solving skills, for the immediate feedback they provide, and for the incentive to keep up to date with course material:

‘tutorial worksheets and online assignments were a great help’

‘The online assignments were extremely helpful as it tested whether I was capable of doing the calculations or not’

‘The online assessments are very helpful for testing your problem solving, as in contrast with regular assignments where it may be a while before you know if you did anything wrong, in the online assignments you can revise your method until you get the right answer, and you will know straight away where you went wrong.’

‘Online assignment were particularly helpful as they made sure you kept up to date with class work’

‘Having access to past papers and solutions was very helpful as were the online assessments.’

‘More online assignments would be helpful as its nice to be graded instantly on work rather than doing it and then having to wait for the tutorial to come around to see if you have attempted the question correctly.’

Overall, the project not only fostered sustained collaboration between mathematics at UCC and mathematics at CIT/MTU, but has also given rise to resources that have had wider impact. The project website www.teame.ie includes fully-tested Numbas questions organised by topic and available as a simple SCORM download. The website includes a digital copy of the TEAME’s Implementation Guide as a step-by-step guide for colleagues anywhere who might wish to introduce e-assessment in their own modules.

A group from the University of Huddersfield visited UCC and CIT in March 2019 to learn from our experience of introducing Numbas-based e-assessment to our modules. The group consisted of two academic members of staff (Dr Ann Smith and Dr William Lee) and two undergraduate students who were working on teaching and learning projects. Responding recently to a question as to how Numbas was progressing at Huddersfield, Dr Ann Smith writes:

Re numbas success, the answer has to be both yes and no!

Making good progress with individual modules but not yet close to the automated testing stage. I’m hopeful we will get there eventually with time.

Incorporating e-assessment into one’s modules is not as easy as one might first think!

Section 6: Conclusion

The use of Numbas-based e-assessments at UCC (and at MTU/CIT) continues. Student engagement with module content has changed radically as a result of the forced move to online learning caused by the pandemic. Even this year, when ostensibly teaching methods have returned to the status quo ante, extensive online content from the last two academic years has been available to students and has led to a shift in the balance in student engagement between synchronous and asynchronous learning. It remains to be seen what the vestiges of this shift in module delivery will remain in the long term, and what this will mean for assessment, and for e-assessment in particular. In the meantime, module content is constantly being refined and updated to maintain currency. Security concerns meant that we had to discontinue use of our standalone server on which we were running Moodle, and then the pandemic hit which made working together much more difficult. Moreover, with all instruction online and no opportunity to meet students face to face, Tom (for one) decided to revert to hand-graded assignments in order to re-introduce some form of direct student-lecturer interaction. With the gradual phasing out of online teaching and online final exams, Killian Walsh, recently appointed to the role of Systems Administrator in our School, has worked to successfully integrate Numbas with UCC's most recently adopted VLE, *Canvas*. This has been successful, so that Numbas-based e-assessments for MA1001 and MA1002, for example, are running smoothly this academic year 2021/2022.

Prior to the pandemic, other Schools in SEFS, for example Chemistry, were interested in seeing whether Numbas could be integrated into their own large modules. Stephen Wills has been central to this TEL dissemination which we hope will resume as post-covid normality returns. It has to be admitted that the pandemic has slowed the development of the Numbas project as it has impeded natural colleague-to-colleague interactions.

Further information on this project may be found at:

The project website <http://www.teame.ie> and the TEAME twitter account @TEAMENUMBAS. The twitter account has > 160 followers. The teame.ie website has had >6600 hits since the beginning across > 5000 users.

Our project is the first Case Study on The University of Newcastle Numbas website.

See also the National Forum for the Enhancement of Teaching and Learning's website

<https://www.teachingandlearning.ie/project/transitioning-to-e-assessment-in-mathematics-education/>

and our article [3].

References

[1] Pauline Fortes and Abdellatif Tchantchane, *Dealing with Large Classes*, International Conference on Mathematics Education Research 2010 (ICMER 2010), Procedia Social and Behavioral Sciences 8, (2010) 272-280.

[2] Veselin Jungic, Deborah Kent and Petra Menz, *Teaching Large Maths Classes: Three Instructors, One Experience*, International Electronic Journal of Mathematics Education, 1, no. 1, October 2006.

[3] Tom Carroll, Deirdre Casey, Julie Crowley, Kieran Mulchrone and Áine Ní Shé. *Numbas as an engagement tool for first-year Business Studies students*, MSOR Connections, Vol. 15, No. 2, 2017, 42–50.