

[O5] e-learning: setting up a diploma in applied chemistry through the university's virtual campus

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ABSTRACT

A new Diploma in Higher Education in Applied Chemistry has been set up through the Virtual Campus of The Robert Gordon University as a result of demand by employers for training in chemistry for employees. This course replaces the former SQA Higher National Certificate in Applied Chemistry which was taught by day release. Demand for the day release course had shown a significant drop in numbers attending the course and yet the University received many enquiries for part-time modes of study. However the demand for the course was varied, some requiring distance learning, some twilight or evening classes and a few still for day release. This paper deals with our experience in setting up a distance learning course on a Virtual Learning Environment.

INTRODUCTION

For over 20 years The Robert Gordon University (formerly Robert Gordon's Institute of Technology and RGIT) has been delivering a course in Applied Chemistry on a day release basis leading to the Scottish Qualifications Authority (SQA) award of a Higher National Certificate (HNC) in Applied Chemistry. Students used to study for an Ordinary National Certificate (ONC) in Applied Chemistry at the local Further Education College before entering the HNC in Applied Chemistry course,

which was equivalent to year two of a Scottish University degree programme.

Traditionally ONC and HNC were part time courses whilst Ordinary National Diplomas (OND) and Higher National Diplomas (HND) were full time courses. There is also a difference in terms of the number of credits these qualifications carried: HNC courses have 12 credits whilst their counterparts, HND have 30 credits. ONC courses have now been dropped and in its place Aberdeen College runs an HNC in General Science (level 1), which gave entry into our level two HNC in Applied Chemistry. Considerable confusion was therefore generated as students perceived that they were taking courses at the same level rather than different levels.

The qualifications of ONC, OND, HNC, and HND were originally awarded by the Scottish Vocational Education Council (SCOTVEC) whilst secondary school qualifications – 'Highers' – were awarded by the Scottish Examination Board (SEB). In a rationalisation of awarding bodies in Scotland, there was an amalgamation of SCOTVEC with the SEB to form the Scottish Qualifications Authority (SQA). This has resulted in a review of courses and levels and the development of the Scottish Credit and Qualifications Framework (SCQF). The SCQF level 6 is set as the Scottish secondary school 'Higher' qualification, SCQF 7 as 'Advanced Higher' HNC, or year 1 Scottish University, SCQF

8 as HND/ year 2 of Scottish University, SCQF 9 as an Ordinary Degree and SCQF 10 as an Honours Degree. Thus SQA now regards all new HNC courses to be at SCQF 7 whilst an HND is at SCQF 8. The HNC in Applied Chemistry had thus become an anomaly as its contents were at SCQF 8 yet its title now implied SCQF level 7.

We have also seen a large fall in the number of students enrolling onto the day release course as fewer and fewer employers were willing to release their employees for a whole day. There has been however, an increased demand from employers and learners for courses in science following a part time mode of learning but some requests were for twilight or evening classes, some for distance learning whilst others would still prefer the day release mode. The requests are also for a broadening provision of syllabus from chemistry into biological sciences. To satisfy this demand it was decided to provide a Distance Learning course delivered through the University's Virtual Campus.

THE VIRTUAL CAMPUS



The University's Virtual Campus, which hosts a considerable number of open and distance-learning courses, provides a comprehensive infrastructure for distance learning, providing the flexibility for students to study in their own time. The Virtual Campus facilitates interaction

between staff, students and others, supporting course delivery, tutoring, and discussions. It attempts to recreate facilities to be found on a traditional university campus, such as for example the library and on-line resources, bookshop, meeting rooms, community groups etc. A large part of the students' learning experience is delivered by tutorials online or by e-mail. The practical elements of the course are taught by two one-week summer schools at which attendance is required.

THE COURSE AIMS

The course aims to develop students' knowledge and understanding of chemistry. It is intended to provide a course on which employers may enrol their employees as part of a professional career structure and it will enable employees, who went into employment straight from school, to gain qualifications at a Higher Education level. It provides fundamental knowledge and scientific skills for employees working in chemistry based employment.

THE COURSE CONTENT

On completion of eight modules (4 modules per year) the students will be awarded a Diploma in Higher Education (Applied Chemistry) from The Robert Gordon University. The modules on the course are shown overleaf.

Students must study Analytical Science 1 and have the free choice of seven other modules from the remaining nine modules. However the students are strongly advised to take at least one of the practical modules. Practical Work 1 is taught by dry laboratory exercises and a one week summer school in late August. Practical Work 2 has more extended work and could be undertaken in the place of work. For students who are employed in laboratories then accreditation of prior learning for the skills they are already using and practising is also taken

Course modules

Analytical Science 1
 Biological Chemistry
 Inorganic Chemistry
 Molecular Biology and Modern Techniques
 Practical Work 1

Analytical Science 2
 Organic Chemistry
 Physical chemistry
 Microbiology
 Practical Work 2

into account when assessing these two modules. Analytical Science 1 is a prerequisite for Analytical Science 2.

For the award of the Diploma in Higher Education in Applied Chemistry the students must pass Analytical Science 1 and a further seven modules from those given above.

DESIGNING THE MATERIALS



The module content was based on the content of the second year modules on the full time degree programme of the BSc (Hons) Applied Chemistry course to ensure that students could progress further with the diploma if they wished. This course has been taught for many years and has undergone several revisions so that we were confident that we had a viable programme of learning at second year level. Lecturers had well written lecture notes which had been tried and tested with the full-time students; however the conversion of this material

to distance learning materials was not so easy. The material now had to be able to be studied in isolation with no member of staff present. Lecture notes had therefore to be expanded and written in ways that are attractive to students. They had to be easy to follow and also needed to contain all those points of information and explanation which would be given to the face-to-face learners.

Each module was divided into topics which had to be small enough for a distance learner to be able to complete in a week. Staff therefore decided to base the topic size around their lecture provision. As each of the semesters at The Robert Gordon University has twelve teaching weeks the modules were not to contain more than twelve topics. A page limit on the topics was not set because there would be varying numbers of diagrams and pictures in the topics depending on the nature of the material. For topics such as Thermodynamics and Kinetics which contained numerical work – calculations, graphs etc, the staff were encouraged to include worked examples and several practice examples. Self assessed questions were also included in the text.

The first modules written were Analytical Science 1, Organic Chemistry and Physical Chemistry. The production of the graphical material for these modules was well within the capabilities of the members of staff writing them, however production of some of the other modules such as Biological Chemistry, Microbiology and Inorganic Chemistry began to show up problems which had not been considered at the start of the project. These modules all needed diagrams and pictures which were beyond the graphical skills of the

staff writing these materials. Under copyright rules staff could not scan in diagrams from text books and hand drawn diagrams were unacceptable to quality control staff of the Virtual Campus.

The writing team therefore decided that there was need to employ a graphics artist who was able to produce some excellent graphics for the distance learning material. For biological chemistry two chapters of the recommended text book were made available in digitized form by working with the Robert Gordon Library which paid to have these chapters converted using the HERON project (1). HERON (Higher Education Resources Online Network) offers a national service to the UK academic community for copyright clearance, digitisation and delivery of book extracts and journal articles. Both of these solutions were successful and for future projects we would employ a graphics artist from the beginning.

ENGAGING THE STUDENTS

The Virtual campus is set up so that only those students who are registered on the Diploma course can have access to the module materials for their course and the other facilities in the Virtual Campus. Students are enrolled onto the various modules by the course administrator as and when they are studying that particular module. This creates the various module groups which consist of the students studying the module, the module tutor, the senior course tutor and the administrator.

E-mail contact with the students is carried out through the Campus although a copy of their reply to the tutor appears in the tutor's Outlook e-mail box. A direct link allows the tutor to reply through the Virtual Campus. In this way students e-mail addresses can be hidden from each other and complete security exists. The tutor is able to post messages to the whole module group and students are able to email each other by setting up a contact list within the Virtual Campus.



However email doesn't allow open discussion and so an alternative way of communicating has also been set up. This is by using a Discussion Forum. Here the student or tutor can post messages and everyone enrolled in the group is able to read the message and post a reply. This is particularly useful if a student poses a question about the module as everyone benefits from the tutor's reply. The Discussion Fora have a number of strands to them: Welcome, Module content, Module activities and Module Administration.

However the most difficult task has been to get the present students to use these fora to interact. Ideally they should be able to answer queries that are posted between themselves rather than waiting for the tutor to answer each query. In the same way that full-time students might sit around discussing problems they have experienced with the course. Some students have indicated that they feel isolated studying the material by themselves yet participation in the Discussion Fora has been very poor to date.

Feedback from the students on the pilot study has indicated that it can be very boring reading material on the computer or by downloading and printing the material and so we are seeking ways of enhancing the module material with a variety of computer aided activities. These have included the insertion of suitable websites, the use of formative multiple-choice tests and the use of crosswords (2).

Future plans are to further enhance the course with more interactive activities thus engaging the students' interest. The Virtual campus has an introductory module for all students independent of course but the development of a more specific welcome and introductory short module would help to engage the students from the start.

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[O6] Supporting maths and physics through the PPLATO resources

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THE CONSORTIUM PARTNERS

Brunel University
University of Newcastle
Open University
University of Plymouth
University of Reading (Lead Institution)
University of Salford

PRIME CONCERNS OF PPLATO

Teaching mathematics to physics undergraduates.

Widening participation in undergraduate physics.

Using new learning technologies to address the two central issues above

PEDAGOGIC ISSUES

How can text-intensive subjects, such as mathematics and physics be presented effectively on screen?

To what extent can CAA technology help with assessment?

SCOPE OF PPLATO RESOURCES

A comprehensive flexible digital resource for the support of physics and mathematics

teaching for physics undergraduates at Level 0 and Level 1.

Includes materials for teaching, testing, diagnostics, practice and tutorial support.

Includes a Foundation Programme.

BRIEF DESCRIPTION OF RESOURCES

h-FLAP: A large hyper-linked teaching resource of Level 0 and Level 1 physics and mathematics, with links to a hyper-glossary.

Maths for Science: A hyper-linked teaching resource of Level 0 mathematics for science students.

Interactive Mathematics: A hyper-linked tutorial package of Level 0 and Level 1 mathematics topics for science students.

h-Tutorials: A hyper-linked tutorial package of Level 1 and Level 2 mathematics topics for science students.

Computer assessment: A computer assessment package to generate an effectively unlimited question bank with intelligent feedback on Level 0 and Level 1 maths, useful for diagnostics, monitoring and for formative or summative testing.

Online Foundation Programme: A complete flexible foundation programme for preparing

students for entry into physics-related and mathematics-related degree courses and for use in continuing professional development in mathematics or physics for those in employment.

INTEGRATION OF RESOURCES

Five resources, with different styles, accessed via an HTML interface.

Flexible interface, can link a tutor's course to the PPLATO resources allowing flexible learning for students.

ASSESSMENT IN PPLATO

Teaching texts and tutorials have embedded formative questions with rapid feedback & all under student control. There is essentially unlimited CAA with intelligent feedback for summative and formative use, including mastery learning.

THE FOUNDATION PROGRAMME

This is a programme in physics and mathematics at Level 0 to prepare students for university entry and to widen participation in undergraduate physics. It may also be used for individuals seeking training in physics and/or mathematics and for continuing professional development. The programme has extensive CD resources and online tuition. It may be studied full-time or part-time and either physics or mathematics or both may be studied. There is an optional laboratory school.

The programme is available to HEIs within their accredited programmes or to individual students with no institutional affiliation. It provides a benchmark programme for university physics/engineering entry.

IMPLEMENTING THE RESOURCES

Departments select those parts that they wish to implement and in what way.

This may vary from full course design to background teaching support.

Departments agree to evaluate those resources used (instruments for evaluation are provided). The resources are supplied free to HEIs in sector and there is support with implementation and evaluation.

RESOURCE DEMONSTRATION

The full resource will be demonstrated at the meeting.

FURTHER ENQUIRIES

e-mail is pplato@rdg.ac.uk

website is www.pplato.rdg.ac.uk

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[O7] Learning and teaching via online maths tests

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ABSTRACT

This paper describes the development of online mechanics tests written as part of the PPLATO (2005) project. By using random parameters within questions, including within MathML for dynamic equations and SVG for dynamic diagrams, many millions of (algebraically and pedagogically equivalent) question realisations can be generated, at runtime, from a single question style. We describe various technical features of MathML, SVG and question & outcome metadata and tagging, focussing on the possibilities and problems they raise. We also report on a FAST (2005) experiment designed to study the efficacy of feedback.

INTRODUCTION

This paper builds on recent work (Greenhow, 2004; Gill & Greenhow 2004; Martin & Greenhow 2004; Nichols, Greenhow & Gill 2003) that has resulted in a fairly extensive CAA system called Mathletics. As the name implies, Mathletics seeks to provide a 'training facility' whereby students at GCSE to second year undergraduate level can take diagnostic, formative or even summative assessments. The following are important Mathletics features:

(1) a variety of question types have been developed with Question Mark's open code QML language (a type of XLM language that is

interpreted by a browser – specifically IE5 or above – to display the question). These types include the usual multi-choice, multi-response and numerical input (with error range), but also responsive numerical input where commonly occurring wrong answers are recognised, confidence-based questions similar to those of LAPT (Gardner-Medwin, 2005), hot line questions where students usually have to identify a line in a worked solution that contains a mistake, and sequential questions where a wrong answer in part i) is followed through in the rest of the calculation and used to mark the method for subsequent parts of the question (the user's input for parts ii) etc will be wrong even if the correct method is used).

(2) roughly 1000 question styles have been added to the question database so far, grouped into libraries and sub-libraries according to mathematical topic. Where to put question styles can sometimes be a problem; the integral of e.g. $x\sin(x/2)$ could be included in any of the integration: substitution, trig functions or by-parts sub-libraries. We generally list according to the most advanced skill being tested, in this case by-parts, but this requires a judgement. Each question style results in thousands or even millions of realisations seen by the users through the use of random parameters and, sometimes, words. These parameters are carried through the question, including MathML-based equations and diagrams using SVG, and are used in the stem, correct answer (or key), marking and feedback.

(3) in the case of multi-choice or responsive numerical input, distracters are generated by applying algebraically/algorithmically encoded mal-rules. A mal-rule can be defined as a structured, but incorrect, way of doing mathematics, for example $(a+b)(c+d) = ac + bd$. An advantage of this approach is that targeted feedback can be given for any student choosing that particular option for multi-choice questions or that particular number for responsive numerical input; the above mal-rule might trigger a message '*You have forgotten the cross-terms*'.

(4) metadata is added to each question description that characterises its algebraic and pedagogic structure. In the above example, negative values of any of the parameters a, b, c and d would change the skills set needed to answer the question; thus although the algebra is the same, the signs of the parameters also need including in the question metadata. For multi-choice questions, outcome metadata that characterises the mal-rule behind each distracter is needed to make sense of the answer files (these will include the parameter values so recognising which distracter has been chosen may not be easy without this metadata).

(5) font size/colour and background colour can be set up by each user in a cookie; on entering a question, this information is read and used by the question, including equations and diagrams. For the resizing diagrams, line thickness can also increase with increasing font size. We think this accessibility feature will be of use to dyslexic and partially-sighted students.

(6) questions are tagged according to difficulty level and national syllabus (we used Edexcel's specification 2005). The questions here presented are all tagged M1, Mechanics 1. On creating an assessment, an author can search on tags, specifying, for example, that only easy questions are to be asked. Tags are also read by the 'Related material' button in the feedback page.

(7) much of the above relies on calling functions, held within our template files, see e.g. Martin & Greenhow 2004. They are basically of two types; those that return the result of a calculation, e.g. multiply two polynomials, and those that return MathML or SVG strings to display mathematics or diagrams correctly e.g. x^2 not $1x^+2$, cancelled fractions etc. As well as dramatically simplifying the coding of each question, these functions can be used for any web page, for example to produce learning material that, on reloading, generates equations and diagrams that are consistent with the randomly chosen parameters and users accessibility preferences.

This paper demonstrates some of the above functionality via the screenshots below. We also describe our approach to question design and the results of a study to determine the efficacy of the feedback we have written for each question. Actually most of the authoring work involved writing sufficient feedback, and at the correct level to engage the students and affect their future attempts at similar questions (known as feed forward). With FAST (2005) funding we devised a series of pilot studies with our first year students taking a mechanics module aimed at quantifying their abilities and understanding their behaviour/use of the feedback offered.

DISCOVERING MAL-RULES

In order to ask pertinent questions, to structure the stem and feedback in a way that relates to students and to formulate the mal-rules built into some question types, it is very useful to have a clear idea of where students make mistakes. At present there are two types of source: teachers are a good source of anecdotal evidence, but this can be unstructured and unquantified; and student work, such as their workings in class (see below) or their scripts from formal assessment. Chief examiners' reports (see e.g. Edexcel 2005) provide useful information on which

exam questions students found difficult, but are not specific enough on why they have difficulties or how they actually went wrong. We have therefore analysed several hundred scripts from Brunel University's foundation and first year mathematics and mechanical engineering students, and Reading University's foundation and first year physics students. This has proved a rich source (!) of mal-rules and their popularity, to be reported on elsewhere. We have been able to build in most of these into our questions; in the next academic year, we will have many hundreds of answer files with mal-rule (outcome) metadata that will help us reformulate less successful questions, write new ones and inform teaching staff and the curriculum in general.

TYPICAL QUESTION AND FEEDBACK SCREENS

Figure 1 (overleaf) shows a typical (annotated) feedback screen for a typical multi-choice question. It was wondered if the feedback was too extensive and might simply be ignored by students. In fact, students spent a lot of time studying the feedback, even writing it all down (until we pointed out the helpful print button at the top of the screen). Some students were also found to be choosing 'I don't know' or inputting random numbers so that they could read the feedback before making a serious attempt on similar questions. In short, the feedback is seen by students as a primary learning resource, rather than a check on their answers and knowledge.

TRIALS OF QUESTIONS

We set up and ran 6 staffed sessions throughout the autumn of 2004 to pilot the tests in controlled conditions (15 students took part and tests were available and used outside these sessions too). Each session was timed to follow material just covered in class. In addition to seeing if students could use the software (very few problems were encountered

with the screen navigation/layout) and if the students enjoyed, or at least engaged with, the questions (generally they did), we wanted to find out how effective the feedback provided was, in terms of:

- helping students do similar problems immediately/1 week/2 months, after having read the feedback.
- helping students do related but dissimilar problems immediately/1 week/2 months after having read the feedback.
- getting students to spend time on task and properly engage with the material to affect a change in their learning behaviour.

It quickly became apparent that we had overestimated the number of questions that students could attempt in the 50-minute slot. Perhaps this arose because they spend so long looking at the feedback, but most students only completed 2 (out of an expected 5) questions.

After four of the sessions, students were unexpectedly asked to collect all their paper workings, name them and give them in. The aim was to see if students were emulating the worked solutions presented in the feedback. Conclusions were difficult to draw from this so we decided to look specifically for four indicators – units, diagrams, solution layout and vector notation. We analysed the past 5 years worth (1999/2004) of exam scripts for the mechanics module, in total 125 scripts and this year's (2005) 15 exam scripts (in brackets). 42% (45%) of students were using units when stating their answer and/or throughout their method. 35% (90%) of students were making use of diagrams in questions where they were needed. 37% (68%) of students were showing their method in a step-by-step layout where they explained or stated any formulas that were being used and any conclusions they derived from their solution. 61% (65%) of

Figure 1: A typical feedback screen with annotation

Physics (Statics) (Resolving forces in equilibrium) (20)

Print this screen Colours & Fonts MathML

Score so far: 0 out of 3. 0%

1 of 1

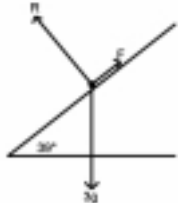
A particle of mass 3kg rests in limiting equilibrium on a rough plane inclined at 39° to the horizontal.

Find the coefficient of friction between the particle and the plane.

Take the value of g to be 9.8ms^{-2} .

6) You did not know! It should have been $\mu = 0.81$.

The force diagram is:



Question is restated in the feedback

Question parameters that change within specified limits

SVG diagram has correct parameters displayed and the angle is accurately drawn. The coding calls component line functions within a template file (themselves calling the accessibility data). The resulting strings are concatenated in the question and passed to the SVG viewer plug-in automatically by the browser.

Physics (Statics) (Resolving forces in equilibrium) (20)

Resolving perpendicular to the plane gives:

$$R - 3g \cos 39 = 0$$

$$R = 3g \cos 39 = 22.848091$$

Resolving up the plane gives:

$$F - 3g \sin 39 = 0$$

$$F = 3g \sin 39 = 18.50282$$

Since the particle is in limiting equilibrium $F = \mu R$

$$18.50282 = \mu 22.848091$$

$$\mu = \frac{18.50282}{22.848091} = 0.810784$$

Therefore the coefficient of friction between the particle and the plane is 0.81.

Related material

0 out of 1

Please write the question down and ask your teacher/lecturer

Continue

Fully-worked solution in MathML with question parameters taken through

Button reads syllabus tag and displays a message about A level module M1

General feedback and advice

students were indicating vectors correctly. The situation is complicated by a change of lecturer in 2002, which also was a low year, at 30%, for correct showing of vectors, but two of the trends are quite dramatic and provide some support for the notion that the feedback is having a beneficial and lasting effect on the students.

CONCLUSIONS

Mathletics is due to be released this summer, ready for use in the next academic year. By writing a substantial number (about 100) of question styles that incorporate random parameters, we have built a useful resource that spans the M1 Mechanics module at A level and hence is useful to a range of school, college and university students. Although we will be collecting further evidence about the effectiveness and student reaction to these questions, results obtained the evaluation project have been encouraging. Students spent a lot of time reading the extensive feedback and this appears to have positive effects on them. The questions were being used as a learning tool alongside lectures and seminars.

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[O8] Mathtutor: supporting students in learning mathematics

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ABSTRACT

'*mathtutor*' is a new mathematics e-learning resource for mathematics and science education, which delivers diagnostic tests, video tutorials, interactive exercises, animations and printable text via DVD and the Internet. It has been designed to support students through AS and A2 level mathematics to 1st-year undergraduate programmes in engineering, mathematics and the sciences, and represents the culmination of extensive collaborative work between the EBS Trust and the universities of Leeds, Loughborough and Coventry, supported by funding from HEFCE (FDTL4) and the Gatsby Foundation. This paper begins by highlighting some of the current problems surrounding mathematics in the sciences and outlines the background to the development of '*mathtutor*'. It goes on to describe the structure and key features of this learning resource and concludes by summarising a proposal to apply the same technologies in the development of a multimedia and e-learning resource for mathematics support for students of the life sciences. The latter will apply a contextual learning model in creating a problem-solving e-learning environment.

BACKGROUND

There has been growing concern within the sciences about students' mathematical abilities. The problems have been well documented by disciplines ranging from engineering, to the life sciences (Phoenix, 1999; Lenton and Stevens, 1999; Savage and Hawkes, 1999; Tariq, 2002a), and have been highlighted by some professions, such as nursing (Cartwright, 1996; Hutton, 1998; Bishop and Eley, 2001).

In the life sciences, which encompass a wide diversity of disciplines, the range and level of mathematical skills required of undergraduates inevitably vary; however, all require a core of numerical ability (Phoenix, 1999). Over recent years concerns have been expressed that many students lack confidence in their ability to deal with basic mathematical concepts and are unable to calculate accurately and efficiently even when using a calculator. They are often unable to manipulate or appreciate numbers and equations, to use scientific notation or to explain and make predictions from data presented in graphs, charts and tables (Lake, 1999; Phoenix, 1999; Tariq, 2002a, 2002b, 2003). Many life science students enter their degree programmes possessing only GCSE Mathematics (or its equivalent) and only a minority possess a

higher mathematics qualification (e.g. at AS- or A2-level). Concerns have been expressed that changes to GCSE mathematics curricula over the years have reduced the expected level of ability of students entering life science degree courses. But even allowing for this, university departments should be able to assume that most students can manipulate fractions and decimals, handle powers of ten and be able to plot and interpret graphs.

Universities have been forced to expand and the cohort of students arriving each year is not only larger but much more diverse in terms of the students' prior academic experiences and achievements. Twenty years ago our science undergraduate populations were far more homogeneous. Nowadays students embarking upon science degree programmes possess a more diverse portfolio of qualifications, ranging from GCSE, through AS- and A2-levels, to diplomas, and may come from work-related backgrounds, as well as from conventional schools and further education colleges. Changes to secondary level mathematics syllabuses in the 1980s and 1990s have allowed students to achieve good grades without having been taught some of the more difficult concepts and skills. In addition, Lenton and Stevens (1999) suggest that difficulties with mathematical concepts in science lessons may arise from the teaching of facts and skills as opposed to teaching through conceptual understanding by science teachers and unqualified teachers of mathematics. The latter situation has been compounded by the difficulties associated with finding sufficient professionally qualified mathematics teachers (Smith, 2004). Today's students need to be provided with new ways of learning maths, and to be offered fresh perspectives on their chosen discipline.

PROVIDING STUDENT SUPPORT IN MATHEMATICS

Universities have had to implement a variety of strategies aimed at supporting their under-

graduates' mathematical knowledge and skills. Many science disciplines have adopted a range of strategies to help identify entrants' specific difficulties regarding their basic numeracy skills and the mathematics regarded as an essential foundation for subject disciplines, and to support students' academic development (Tariq, 2004). Learning support strategies adopted include:

- *formal mathematics courses or teaching sessions* – the latter may form part of either foundation quantitative subject-specific modules or more generic skills modules for first-year undergraduates. Their primary aim is to ensure that all students understand the basic mathematical concepts necessary within the discipline. But delivering such courses can often feel like an up-hill struggle!
- *tutor-led small group tutorial sessions or workshops* outside the formal curriculum. The problem often encountered here is getting students to engage in a process that can appear to them as offering few returns in terms of any summative assessment and final qualification.
- *dedicated mathematics learning support centres*. Some 50% of institutions have such facilities. Where available, these have proved successful and some provide a most professional service. However, in the main they seem to be used by students of maths and maths-based subjects and the proportion of students using them can be relatively low. There is also the recognition that they might appeal to those students who already possess a high level of maths competence and seldom draw in those students in greatest need of help and support.
- *computer assisted learning (CAL) materials*. These are often self-paced

tutorials and assessment exercises, developed in-house, using software such as QuestionMark™ or web-development software (e.g. Macromedia® Dreamweaver®), and tailored to satisfy the demands of a particular discipline or specific module.

- *self-help and independent learning resources*, e.g. handouts, instructional guides and/or textbooks (e.g. Phoenix, 1997; Foster, 1998; Cann, 2003, www.mathcentre.ac.uk).

All these approaches are valid but are often local to one institution. What was needed was to build on these activities and consider a national resource that would be available to all students and their teachers.

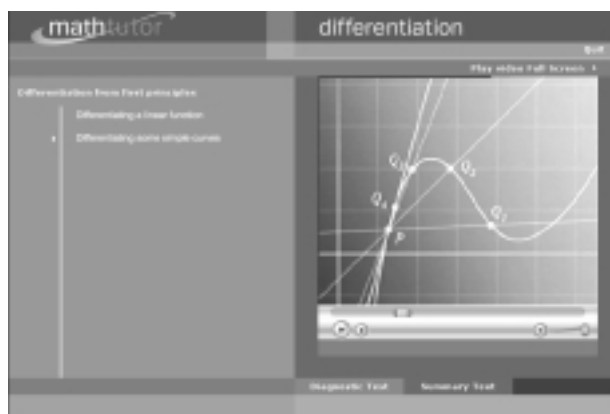
ENTER MATHTUTOR

'*mathtutor*' and its sister website '*mathcentre*' represent exciting new generic mathematics learning resources, based on the tutorial model of teaching and making extensive use of video and animation (Fig. 1). '*mathtutor*' consists of a series of six DVD-ROMs covering over 80 topics in arithmetic, algebra, geometry, trigonometry, vectors, functions, graphs, sequences and series, differentiation and integration. The level straddles GCSE, AS and A2 mathematics, with a nudge into 1st-year undergraduate programmes. '*mathtutor*' has been designed as a resource to support individual learning, rather than as a discrete course. Each topic is prefaced with a diagnostic test and has associated with it pages of interactive exercises, some 2000 in all. There are over a hundred video tutorial sequences, some of which are quite long – up to an hour – but each video tutorial has a menu for easy navigation. Students appreciate the style of tuition, with a 'live' tutor providing detailed explanations at an appropriate pace for the learner. The built-in facility to stop and re-play each video tutorial is particularly advantageous and the

feel of the tutorials is very much one of personal and intimate teaching. When the algebra section was evaluated in 2004, more than 80% of students found the materials useful or very useful.

'*mathtutor*' has been produced by a team led by the University of Leeds and the EBS Trust who are experts in new media production. On the team are academics from the universities of Coventry and Loughborough together with television producers and technicians. Funding has been jointly achieved through a HEFCE's FDTL4 grant and a matching grant from the Gatsby Foundation. It is anticipated that all the materials will be published in summer 2005, in both disk and web formats.

Figure 1: Sample screen from '*mathtutor*' illustrating an animation for 'Calculus from first principles'



ADAPTING 'MATHTUTOR' FOR THE LIFE SCIENCES

The challenge

A team of academics is currently working in collaboration with the EBS Trust to adapt aspects of '*mathtutor*' for life science undergraduates. Our challenge is to try and address some of the key issues and concerns highlighted above. In short, our aim is to produce a national multimedia e-learning resource to support students in their

acquisition, practice and application of those mathematics skills essential to the life sciences. Since the life sciences include a plethora of specific disciplines, the first questions we must answer in formulating a strategy to meet this challenge are '*Which life sciences will we cover?*', '*What mathematics are regarded as essential to these disciplines?*' and '*What learning model should we use?*'

An initial pilot project will select a single discipline (e.g. microbiology) or aspect (e.g. cell biology) to cover. Few would argue that it is possible to identify a core level of mathematical ability required by all students embarking on life science degree pathways (Phoenix, 1999; Tariq, 2004), e.g. the essentiality of basic arithmetic; the ability to manipulate algebraic expressions and equations; the presentation and interpretation of graphical data; and if students are to understand movement and rates of change and predict outcomes with confidence they will have to get to grips with elements of calculus.

Our main challenge lies in increasing students' confidence in their ability to engage with the maths, both basic and more advanced, that is an integral part of their life science discipline. The first step involves persuading students that maths can be exciting, that it can provide fresh insights into biological phenomena and that it is increasingly relevant to the life sciences. So how can we get this message across?

Using the power of contextual problem-solving towards an innovative solution

We plan to adopt Coles' contextual learning model (Coles, 1997) and apply it to problem-solving in an e-learning environment. Maths is an exciting subject and should be taught in such a way as to complement the biology, rather than as an abstract necessity. So rather than present students with a range of maths topics and then use biological examples to simply illustrate the application of the

mathematical concepts, might it not be better to take some exciting biological topics, case studies and scenarios, present them in a highly visual manner and explore the mathematics within each – teaching students and enabling them to practise the maths required for them to understand and master the topic? Each case study would demand mastery of one or more particular mathematical concepts and skills. There would inevitably be overlap and reinforcement; several case studies might demand the same mathematical skills and there might be several maths topics associated with any one case study. The principle of this approach is that the context (i.e. the case study) triggers students to want (as opposed to need) to learn the maths. This should appeal to students of the life sciences who would see their own subject area as distinct from others and immediately want to delve into a particular scenario. Associated with each case study would be a number of questions, tasks and calculations for students to complete. In addition, students would be provided with online video-based tutorial support for those maths topics and concepts with which they lacked confidence or with which they were unfamiliar; this would be similar to the format successfully applied in '*mathtutor*'. They would also be provided with the opportunity to practise and apply their skills to new case studies, thus linking theory to practice.

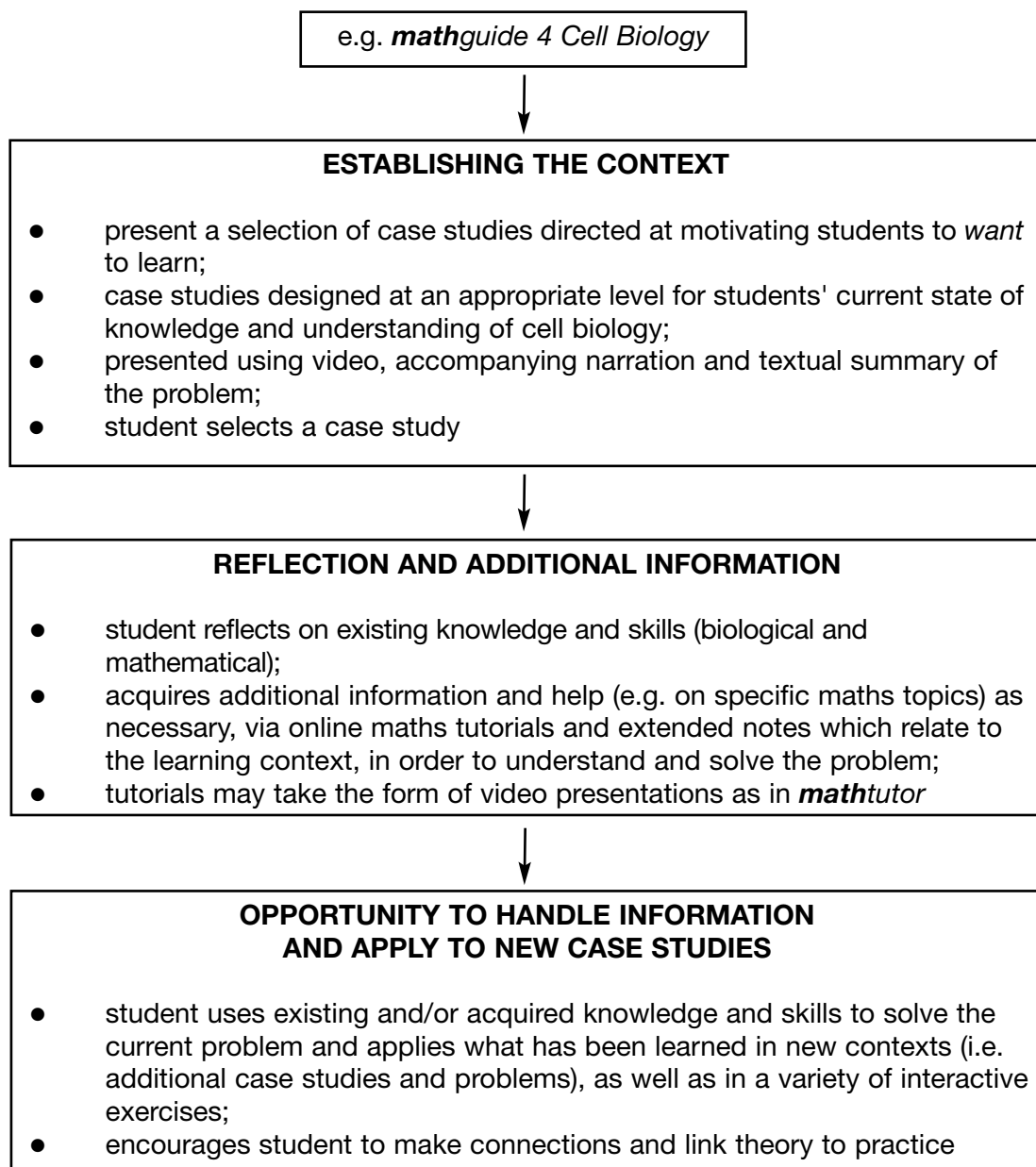
The overall structure and navigation through this innovative learning resource are summarised in Figure 2. Upon selecting a particular discipline or specific aspect, a student will be presented with a list of relevant case studies from which they may make their selection. Each case study will be delivered as a filmed and narrated story involving a real event or biological phenomenon and the necessary mathematics associated with it. From this case study learners will be able to navigate to one or several sections of maths topics required for their better understanding of the maths associated with the case studies. The latter would be presented by a real tutor as

in '*mathtutor*' and there would be an extended text version of each tutorial available for printing. What would be interesting would be to explore supplementary exercises which would enable learners to practise the maths they had learned, but to make such exercises relate directly to appropriate biological case studies, i.e. once again contextualising the maths. Here we could also incorporate extensions to the maths, taking the learner to new and exciting

developments in biology which involve fascinating maths.

Although the aim is to create a form of problem-solving distance learning or mediated self-study tool, the resource developed could be integrated into lectures, tutorials or practical classes within specific modules or programmes.

Figure 2 Proposed model for a life sciences multimedia learning resource



Scope of the project

The project aims to embrace most of the principal disciplines within the life sciences and to cover the maths necessary for a full understanding of all the case studies presented. The resource will offer something of an alternative course in maths for the life sciences, with the emphasis on the life sciences first and then the underlying maths that students need. We aim to make everything highly visual, realistic and full of movement and excitement.

If you are interested in participating in this project please contact Jim Stevenson (jim@ebst.co.uk) or Vicki Tariq (vtariq@uclan.ac.uk).

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[O9] Counting on numbers – squaring the numeracy divide

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Keywords: numeracy, dissonance in perceptions, confidence

ABSTRACT

Key skills are an important element of the United Kingdom Government's educational agenda (Dearing, 1996; NCIHE, 1997). Nationally recognised key skills include application of number (numeracy). Dearing (1997) emphasised the need for HE institutions in the UK to deliver 'numerate graduates'. Subsequently the Department for Education and Skills' Numeracy Task Force proposed a definition framing the skills that are attributed to a numerate individual (DfES, 1998); however across a range of subject disciplines evidence suggests that a significant number of undergraduates do not match this definition (Phoenix, 1999; Engineering Council, 1995; LMS, 1995; Engineering Council, 2000; Tariq, 2002a; Tariq, 2002b).

Decline in the mathematical fluency of students embarking upon HE courses appears to coincide with low confidence and negative attitudes to learning related to the use and application of numbers (Mackenzie, 2002). This project explores self-efficacy of students when applying numeracy skills and whether a dissonance in perception between students and staff exists. During induction students completed a questionnaire that included items on prior learning experience in numeracy, attitude to numeracy, and perceived confidence in applying particular numeracy skills. Staff completed a related questionnaire of their perceptions of students' abilities in

applying particular numeracy skills. There is a clear dissonance in staff and student perceptions and an apparent lack of confidence and some negative attitudes and concern towards numeracy. Positive attitudes to prior maths learning are noted; as students recognise the situation of numeracy in academic and work contexts. Staff perceptions appear more consonant with male students. The results of the project will be used to inform provision of appropriate support strategies to enhance numeracy skills and increase confidence and capability in their application.

INTRODUCTION

Concern about levels of basic numeracy has engaged politicians, educators and employers alike. Qualifications for 16-19 Year Olds (Dearing, 1996) and the report of the National Committee of Inquiry into Higher Education (Dearing Report) (NCIHE, 1997), in addition OFSTED (1993) and the Basic Skills Agency (1997) following evidence of poor levels of numeracy in the UK school and adult populations. Low levels of numeracy for students entering higher education (HE), across a range of subject disciplines are well documented in the literature (Phoenix, 1999).

Decline in the mathematical fluency of students embarking upon HE courses appears to coincide with affective issues, a so called

'maths anxiety' (Mackenzie, 2002). Presage (Biggs, 2003; Ramsden, 2003) is a key issue, particularly against the backdrop of the 'massification' of higher education (Barrington, 2004; Coaldrake, 2001) and many HE institutions strong commitment to widening participation and lifelong learning. Students enter university with a range of qualitatively different conceptions of and approaches to learning; this will be no different for numeracy and mathematics (Crawford *et al.*, 1998). The aims of this study were to explore the confidence and attitudes to numeracy among level one students studying at the School of Applied Sciences, University of Wolverhampton, and to investigate student and staff perceptions of numeracy and identify any consonance or dissonance that may exist.

METHOD

A questionnaire was prepared, the construction of which was influenced by the ideas of Mackenzie (2002) and Tariq (2004), and issued to year 1 Applied Science students during induction week. Questions related to three themes; prior experience of numeracy, attitude to numeracy and perceived confidence in numeracy application. This third theme was further subdivided into student and staff perceptions. A five-point Likert scale of 'Strongly agree', 'Agree', 'Neither agree nor disagree', 'Disagree' and 'Strongly disagree' was used for assessing prior experience and attitude, and a four-point scale for rating confidence C=0 (not at all confident), C=1, C=2 and C=3 (very confident). Students were asked to rate their personal confidence (self-efficacy) in each of twenty eight numeracy skills (after Tariq, 2004) and staff asked to rate their perceptions of what level of confidence would be expected of a level one undergraduate entrant in the same numeracy skills. All students completing the questionnaire were asked to indicate formal mathematical qualifications. The questionnaire was produced using Surveyor by ObjectPlanet software, hosted online and distributed via a URL link

from the University virtual learning environment, WOLF (Wolverhampton Online Learning Framework) and the University email system. Statistical analysis using Mann-Whitney U Test was performed in SPSS version 11.5.

RESULTS

Summary of Questionnaire Findings

160 fully completed questionnaires were returned, from across the School of Applied Sciences, which comprises four Divisions: Biomedical Sciences, Biosciences, Environmental Sciences, Analytical Sciences and Geography (EAS) and Psychology. 31 academic staff, all involved in year 1 undergraduate teaching returned fully completed questionnaires.

Prior Experience and Attitude to Numeracy in year 1 undergraduates

67% of the student respondents were female, and 33% male, which mirrors the gender demographic of the School. A significant proportion of the students (85%) have passed GCSE maths or equivalent, with 28% of students having studied maths at AS level and 8% at A2 level. This prior learning profile is similar to that reported by Mackenzie (2002). The age profile of the students is 18-41 years; hence non-traditional entrants may well have more distant experience of maths; however 8% of students have gained a qualification in maths during an Access course, and 17% report Key Skills qualifications in maths.

The majority of students (75%) report having enjoyed maths at primary/first school; this positive view of maths is continued at secondary/high school, with 67% of respondents agreeing with the statement. Half of the students (57%) say that they find doing number skills (sums) easy, and 61% intimate a willingness to learn new number skills.

Although fewer than half of the students (49%) report that they like working with formulae and equations (mathematical constructs), there is widespread acknowledgement and recognition that numeracy is implicit both in terms of academic study and employability, with students expecting to use number skills in modules (92%) and at work (95%). Expectation to work with formulae and equations in modules (83%) and at work (71%) is also recognised.

Approximately a third of students agree with the statement 'I am concerned about learning new number skills', 29% are male and 71% are female congruent with the respondent demographic. There are identical percentages for 'concern' shared by Bioscience and EAS students (39%) with a smaller, yet still significant proportion of Biomedical Science students reporting 'concern' (32%). Data for Psychology students demonstrates a markedly lower percentage of 10%. 'Avoidance' as evaluated by agreement with the statement 'I avoid formal number work'

demonstrates a similar trend overall with 21% admitting to such avoidance, of which 22% are male and 78% are female.

Student and Staff Perceptions of Confidence with Numeracy Skills

Students generally express high levels of confidence about basic statistics; these might be termed basic numeracy skills. Low levels and no confidence are noted for unit conversion, integration, differentiation, molarity and modelling, a common factor being the applied nature of the numeracy skills.

Differences in student and staff perceptions of confidence in numeracy application are evident in 9 out of the 28 numeracy skills. There is a dissonance in perception of the fundamental skills of multiplication, division, decimals, the size of numbers and communicating data, with staff expectation of

Table 1: Prior learning experience and attitude to numeracy of students expressed as percentage frequency (to nearest whole number) (after Mackenzie, 2002)

	Strongly agree (%)	Agree (%)	Neither agree nor disagree (%)	Disagree (%)	Strongly disagree (%)
I enjoyed doing maths at primary/first school	36	39	13	8	4
I enjoyed doing maths at secondary/high school	27	40	12	13	8
I find doing number work (sums) easy	19	38	27	13	3
I want to learn new number skills	19	42	29	8	2
I am concerned about learning new number skills	9	23	40	23	5
I avoid formal number work	4	17	28	40	11
I use number skills in everyday life	24	59	13	4	-
I expect to use number skills in the world of work	42	53	4	1	-
I expect to use number skills in modules for my degree	46	46	5	3	-
I like working with mathematical constructs (formulae and equations)	16	33	26	17	8
I expect to work with mathematical constructs (formulae and equations) in my degree	34	49	12	5	-
I expect to work with mathematical constructs (formulae and equations) at work	23	48	23	5	1

Table 2: Percentage frequency (to nearest whole number) of students agreeing or strongly agreeing with statements relating to maths anxiety and avoidance (Mackenzie, 2002) analysed by Division. Male (○) and Female (▲) students.

	○ All students (%)	▲ All students (%)	Biomedical Science (%)	Bioscience (%)	Environmental & Analytical Science & Geography (%)	Psychology (%)	
I am concerned about learning new number skills	32	29	71	29	39	39	10
I avoid formal number work	21	22	78	17	26	22	10

confidence in ability to apply such skills significantly higher than students' perceived confidence. Conversely, compared to staff, students report higher levels of confidence in the more advanced skills of integration, differentiation and basic statistics.

Differences in perception analysed by Division using a Mann-Whitney U Test indicated a significant difference in staff and student perceptions in all four Divisions of the School.

DISCUSSION

The study revealed that a majority of students demonstrated positive attitudes to their prior learning experience in mathematics at both primary/first school and secondary/high school, 75% and 67% respectively (Table 1). This is consistent with previously reported findings for primary/first schools (Mackenzie, 2002); however the two-thirds of students reporting to have enjoyed maths at secondary/high school is in contrast to Mackenzie's findings. This may be a reflection of the cohort surveyed, in this study the students are level one entrants onto an applied sciences based degree programme; consequently a more pragmatic view might be anticipated, with students viewing maths as integral to pursuing their chosen future

studies, whilst Mackenzie (2002) draws respondents from a range of disciplines that include English, Design and Technology and PE. This pragmatism is reflected by the widespread acknowledgement and recognition that numeracy is implicit both in terms of academic study and employability. This has positive implications for embedding appropriate quantitative tasks in teaching and learning activities, as there appears to be a clear expectation that numeracy skills will be required, a recognition that numeracy skills are important in an academic and broader context that includes employability, Edwards and Ruthven (2003) have reported that young people are more aware of the mathematics embedded in everyday activities than previously thought.

Lack of confidence and negative attitudes, sometimes bordering on the irrational fear of 'all things numerical' (Tariq, 2003; Mackenzie, 2002), is reported by 32% of the students. A greater proportion of those reporting concern were female (71%). Highest levels of concern are shared by Biosciences and EAS students (39%), a trend that is mirrored for avoidance, this may be linked to students opting to undertake academic studies in these areas with the notion that this is a way of studying science whilst avoiding the maths. Despite the high level of confidence reported

Table 3: Differences in student and staff perceptions of confidence in 28 numeracy skills analysed by cohort and Division

Numeracy skill	Complete Cohort	Biomedical Science	Biosciences	EAS	Psychology
	P < 0.05 (two-tailed)	P < 0.05 (two-tailed)	P < 0.05 (two-tailed)	P < 0.05 (two-tailed)	P < 0.05 (two-tailed)
Addition	n/s	n/s	n/s	n/s	n/s
Subtraction	n/s	n/s	n/s	n/s	n/s
Multiplication	sig.	sig.	n/s	sig.	n/s
Division	sig.	sig.	n/s	sig.	n/s
Fractions	n/s	sig.	n/s	n/s	n/s
Decimals	sig.	sig.	n/s	n/s	n/s
Percentages	n/s	sig.	n/s	n/s	n/s
Ratios/Proportions	sig.	sig.	n/s	n/s	n/s
Probabilities	n/s	n/s	n/s	n/s	n/s
Logarithms	n/s	sig.	n/s	n/s	n/s
Calculating things mentally	n/s	n/s	n/s	n/s	n/s
Judging whether your answer makes sense	n/s	n/s	n/s	n/s	n/s
Basic Algebra e.g. rearranging and solving equations, using formulae	n/s	n/s	n/s	n/s	n/s
Using a calculator	n/s	n/s	n/s	n/s	n/s
Appreciating the size of number	sig.	sig.	n/s	n/s	n/s
Exponentials and Powers	n/s	sig.	n/s	n/s	n/s
Scientific notation	n/s	sig.	n/s	n/s	n/s
Unit conversion	n/s	n/s	n/s	n/s	n/s
Reading scales (measurements)	n/s	sig.	n/s	n/s	n/s
Integration	sig.	n/s	sig.	sig.	n/s
Differentiation	sig.	n/s	n/s	sig.	n/s
Interpreting/transforming data from Graphs	n/s	n/s	n/s	n/s	n/s
Interpreting/transforming data from Spreadsheets	n/s	n/s	n/s	n/s	n/s
Interpreting/transforming data from Charts and Tables	n/s	n/s	n/s	n/s	n/s
Molarity	n/s	n/s	n/s	n/s	n/s
Basic Statistics e.g. mean, mode, median, standard deviation	sig.	n/s	sig.	n/s	sig.
Modelling e.g. understanding how variables interact, creating formulae	n/s	n/s	n/s	n/s	n/s
Communicating data	sig.	sig.	n/s	n/s	n/s

by the majority of the students, a dissonance in perception for the fundamental skills of multiplication, division and decimals is apparent, with staff expectation of confidence in ability to apply these basic numeracy skills significantly higher than students' perceived

confidence. This is of particular disquiet given the widespread infusion of such fundamental mathematical concepts in quantitative tasks both within the context of both degree and workplace and links in with the declining standards in numeracy reported. Interestingly,

compared to staff, students report significantly greater levels of confidence with the more advanced mathematical skills of integration, differentiation and application of basic statistics. However evidence from practice and diagnostic tests suggests that there could be an overconfidence expressed. Dissonance in appreciating the size of numbers is also of concern, as many quantitative tasks are underpinned by this concept. Some students appear to have difficulty conceptualising and rationalising calculated values, demonstrating a greater trust in a calculator display, than their own judgement. Staff also expected a higher level of confidence to be displayed in communicating data a key skill for scientists.

Dissonance is most prevalent in the Biomedical Science Division. A high degree of correspondence is noted for the other three Divisions; as a caveat, response rates for students as a percentage of the total student cohort are: Biomedical Science, 49%; Biosciences, 34%; EAS, 11% and Psychology, 6%. This dissonance has implications for both learning and teaching activities and learner support, and will inform appropriate intervention strategies.

CONCLUSION

This study contributes to the debate on attitudes and confidence in applying numeracy and the wider discourse considering declining standards of numeracy in HE entrants. With an agenda for widening participation and lifelong learning, students will enter university with different conceptions of and approaches to learning; and this will be no different for numeracy and mathematics. Clearly negative attitudes and low levels of confidence are incompatible with deeper approaches to learning so staff must avoid perpetuating gender stereotypes. Reassuringly the majority of students in this study report positive attitudes to maths and appreciate the academic and vocational relevance of numeracy; however there is evidence of

concern about and avoidance of maths and lower levels of confidence in 'applied numeracy'. Appropriate support and intervention strategies are required to empower the students, and the results from this study will be used to shape the process. The relationship between students perceived levels of confidence in numeracy application, actual skills and progress need further investigation as the 'problem' of numeracy is a potential barrier to effective learning.

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