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diagnostic testing for mathematics

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published by the LTSN MathsTEAM Project

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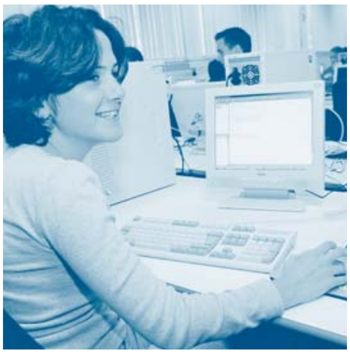

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Foreword

In recent years the number of students entering higher education has increased dramatically. This growth in numbers has brought with it an increase in diversity of educational background.

No longer do the overwhelming majority of mathematics undergraduates have double maths and physics A-Levels or the majority of engineers have maths, physics and chemistry A-Levels. Indeed, on engineering degrees in some universities, students having A-Levels in any subject have become a minority as the numbers with vocational qualifications have steadily increased. Add to these, mature students returning to education through university foundation years or a variety of FE based access courses, not to mention a growing number of overseas students, and it becomes clear that university intakes have lost all semblance of homogeneity.

Faced with this inhomogeneity (and the apparent changes over time in competence of students with the same entry qualification) many universities have introduced some form of diagnostic testing. These tests are usually administered early in the students' university career with two primary aims:

- to inform staff of the overall level of competence in basic mathematical skills of the cohort they are to teach;
- to inform individual students of any gaps in the level of mathematical knowledge they will be assumed to have – so that they can take action to remedy the situation.

The increasingly widespread use of diagnostic testing led the MathsTEAM project to commission a series of case studies to record a variety of practice which can be used by those who are considering whether or not to introduce diagnostic testing at their own institution. The cases studies in this booklet give an excellent cross-section of activities with considerable insight into the practicalities of how to deliver the tests.

The case studies illustrate two delivery mechanisms: paper-based or computer-based. In theory, computer-based diagnostic testing should be simple – off-the-shelf packages such as DIAGNOSYS or Mathletics can be obtained at little or no cost, installed on the university network and away you go. In practice, as some of the case studies point out, life is not quite that simple. Issues such as availability of computer rooms and whether or not students have been given their computer accounts in time can prove to be difficult problems.

Paper-based tests are usually designed in-house – this allows departments to tailor them to find out precisely what they want to know. The tests are usually multiple choice as this allows them to be marked quickly – ideally by optical mark readers, but in reality often by humans.

Diagnostic testing on its own is of limited value. It needs to be accompanied by a programme of support for students whose diagnoses indicate that they need help. Many of these case studies describe the support measures in place alongside the diagnostic test. The range of such measures is testimony to the ingenuity and creativity of the staff involved. There are ideas which can be implemented by those with some funds to spend and also by those operating with minimal resources. And for those wanting more ideas please refer to Maths Support for Students in this series.

Duncan Lawson
Director of Mathematics Support Centre, Coventry University.

LTSN MathsTEAM Project

Funded by the Learning and Teaching Support Network (LTSN), the LTSN MathsTEAM Project (**http://www.ltsn.ac.uk/mathsteam**) has carried out an in-depth survey, examining the following three topics:

- **Maths support programmes and resources,**
- **Current practices for teaching mathematics to engineering and science students,**
- **Diagnostic testing.**

The information has been published in three booklets:

- **Maths Support for Students,**
- **Maths for Engineering and Science,**
- **Diagnostic Testing for Mathematics.**

They each provide a comprehensive collection of case studies, intended to assist you with the challenge of enhancing the basic mathematical skills of engineering or science students.

The contributing authors discuss the execution of current teaching practices based on each of the three topics mentioned above. They talk about the barriers and the enablers in setting up these learning initiatives. For those of you considering the implementation of any of the programmes, each case study provides an opportunity to review the learning processes and tools involved. Each booklet contributes to the transfer of knowledge within higher education communities; each case study offers practical suggestions for you to gain a better understanding of the present situation and related topics that merit further exploration and research.

The UK Mathematics Learning Support Centre

During recent years, throughout the higher education community there has developed a growing need to share knowledge and materials, to develop good practice and stop re-inventing the wheel. Funding has recently been made available for the development of the first UK Mathematics Learning Support Centre - mathcentre.

The Centre will use a mix of modern and traditional techniques to allow both students and university professionals free access to samples of high quality learning materials aimed at alleviating the school/university interface problem. It will also use the resource base created by such projects as the LTSN MathsTEAM.

Further information about the mathcentre can be found at **www.mathcentre.ac.uk**.

Diagnostic Testing for Mathematics

In June 2000, the Engineering Council (UK) recommended to all universities that those students embarking on mathematics-based degree courses should have a diagnostic test on entry (Engineering Council, 2000). Today, throughout the UK Engineering, Science and Mathematics departments are carrying out such tests to assess the current mathematical ability of students.

In most cases the tests take place during the induction week or the first few weeks of the academic year. The methodology for the tests ranges from simple paper-based tests through computer generated multi-choice questions to intelligent diagnostic systems. The tests are not standardised, but in several departments the same diagnostic test has been used over a number of years. The results assist departments to devise approaches to adjust the mathematics teaching and curriculum to the needs of the group and also to inform subject specialists' expectations of their students' mathematical abilities. Primarily the test is being used to help devise strategies to support students with differing attainments.

This booklet contains an in-depth review of current diagnostic testing including the results of a focused project and national survey. There are detailed case studies as well as brief outlines of the actual testing procedures within various institutions. It offers you a chance to explore the growing diversity of good practice found within Higher Education institutions throughout the UK.

Reference: "Measuring the Mathematics problem", published by the Engineering Council, June 2000 (see ***http://www.engc.org.uk/publications/pdf/mathsreport.pdf****).*

LTSN Maths TEAM Project I Diagnostic Testing for Mathematics

National Perspective on Diagnostic Testing

Introduction

Many Engineering, Physics and Mathematics departments throughout the UK are carrying out diagnostic tests to assess the current mathematical ability of students on entry.

Question: In 2001 were new undergraduates in your department given a mathematics diagnostic test?

	Number of Responses	Yes	No
LTSN Engineering	59	38	21
LTSN Maths, Stats & OR Network	54	32	22
LTSN Physical Sciences	50	31	19
The UK Centre for Materials Education	8	2	6
TOTAL	171	103	68

Table 1: LTSN Diagnostic Testing Survey, April 2001

Table 1 shows the findings of a departmental survey conducted in April 2001 by LTSN Engineering, LTSN Maths, Stats & OR Network, LTSN Physical Sciences, and the UK Centre for Materials Education. Academics were asked to confirm whether their department conducted diagnostic tests or not and the results indicated a large number of institutions were. Exploring these facts further, descriptions based on the types of testing were submitted to the LTSN MathsTEAM Project at the beginning of 2002.

In most cases, the diagnostic test was carried out during the induction week or the first few weeks of the academic year. The number of students sitting the test varied; the figures submitted went as high as eight hundred. The methodology for the tests ranges from simple paper-based tests through computer generated multi-choice questions to intelligent diagnostic systems.

The tests are not standardised, but in several departments the same diagnostic test has been used over a number of years. Each covers a variety of mathematical topics and departments use the results to assist the students in different ways – to devise approaches to adjust the mathematics teaching and curriculum to the needs of the group and also to inform subject specialists' expectations of their students' mathematical abilities. Primarily the test is being used to help departments to devise strategies to support students with differing attainments [1].

The results from the April 2001 survey indicated a large number of universities were assessing numerical skills on entry to higher education. To develop a further understanding of the testing process within each of the institutions requires an in-depth analysis of the situation. Paper-based or computer-based the tests rely on an established administrative and testing programme and academic and student participation.

The following section explores the results of a survey, which reviewed 13 departments in-depth using diagnostic testing. A small Working Group developed questionnaires for staff and student. The results can be seen in the section *"Diagnostic Testing within Institutions"*, providing a collection of institutional approaches to diagnostic testing.

An In-depth Study of Diagnostic Testing

At the Undergraduate Mathematics Teaching Conference 2001 a small Working Group was given a remit to consider what action is needed in higher education with respect to diagnostic testing of the mathematics skills of students starting degrees in which mathematics forms a major part; and to survey institutional follow up support. The Working Group was given financial support by a grant from the LTSN Maths, Stats & OR Network. What follows is an account of the work so far and in particular the responses to a survey of academic staff.

Lawson, Halpin & Croft [2], have already listed strategies that institutions might undertake to address the question of what action to take following the diagnostic test. The aim of the Working Group has been to concentrate on that part of their strategy which uses the results of the diagnostic test to specify extra support units for individual students. The survey has examined a sample of 15 of those which provide both diagnostic testing and follow-up support, and those which provide testing without follow-up support, noting both paper and computer-based tests and follow-up. Visits have been made to 13 of these institutions; each visit has included the completion of questionnaires by randomly selected students, as well as the completion of a second questionnaire by the member of staff responsible for the diagnostic testing.

The institutions visited have been chosen due to their target intake and to cover a variety of testing and follow-up procedures in the present survey. The types of degree covered vary from those which are largely mathematical to those in which mathematics is a subsidiary subject, e.g. for engineering. So far the survey has illustrated a wide variety of practice, even between institutions that appear in other respects to be relatively similar.

The detailed study was carried out in September/October 2002 during which time the institutional diagnostic testing was taking place. The testing procedures were observed by on-site visits and questionnaires. A large amount of data was collected which is still being analysed. Nevertheless the results already show some very interesting results (see Table 2). In particular note the number of institutions who have invested in writing their own diagnostic test and those who would use a national test if it were made available. It is evident that although many institutions do provide support for students who perform poorly on a diagnostic test, this is usually staff intensive and that as yet the use of CAL in this area is not widely supported. Finally, the apparent decline in student performance is as might be expected but the awareness of academic staff of what to expect from students is of concern. The final report will be available from the LTSN MathsTEAM website.

Questions	% yes
Did the institution write its own diagnostic test?	77%
If a national computer-based test were made available would you use it?	67%
Have deficiencies in mathematics worsened over recent years?	86%
Are there any dedicated support facilities available, “walk in” centres, etc?	67%
Is any use made of CAL material for supporting students?	17%
How many academic staff are up to date with key issues at the school/university interface?	20%
Does a staff development programme exist to ensure staff are informed?	39%
Is there a need for national diagnostic testing?	73%
Would you use a national database of diagnostic questions?	73%
If a diagnostic environment were provided which automatically linked to self-study and support, would you use it?	85%
Should such an environment be offered to schools to help students prepare for university studies?	67%

Table 2: Sample responses from staff questionnaires

Preliminary Recommendations

There is a general consensus of the need for some form of diagnostic testing of students' mathematical skills on entry to HE; there are a wide number of approaches all with substantial merit. Having investigated the responses from both staff and student questionnaires, the Working Group make the following preliminary recommendations.

1. **Advise students of the diagnostic test and supply revision materials *before* arrival.**

Advise students of the existence of a diagnostic test, and supply examples of the questions with admission information, and supply them with suitable revision materials [3,4]. It needs to be made clear that a diagnostic test is not summative, but a means of helping individual students to plan their learning using new techniques such as self managed learning.

2. **Make sure the purpose of the diagnostic test is clearly defined.**

Inform students as to what information is being sought and explain how the results will be used by staff and individual students.

3. **Provide follow up and support.**

Have a clear strategy for remediation; provide support materials and a mechanism whereby students can assess their progress. (This could simply be a repeated attempt at the diagnostic test). Publish cohort results to enable peer reflection on performance.

National Diagnostic Testing Survey

The project described above provided an in-depth analysis of certain institutional diagnostic procedures. The results were based on a cross-section of the total population of those departments using diagnostic testing. During 2002 - 2003 the LTSN MathsTEAM decided to conduct a national survey to try to obtain a more accurate picture of the number of institutions throughout the UK who are using diagnostic testing.

Each of the MathsTEAM members (LTSN Maths, Stats & OR Network, LTSN Engineering, LTSN Physical Sciences and the UK Centre for Materials Education) sent out the questions to departmental contacts. A review of the numerical results on a question-by-question basis is provided below.

The Questions

The physical science, materials, maths and engineering communities were asked the following questions to collate a snapshot of the current situation of diagnostic testing in the UK:

- *Do you use diagnostic testing to assess student preparedness/ability/knowledge?*
- *If a test is used then is it: paper-based or computer-based?*
- *If computer-based, which package?*
- *In what way are the results of the test used or followed up?*
- *Does your department prepare fresher students prior to their arrival at university with regard to their mathematical skills, or general skills?*
- *If a tried and tested diagnostic test was made available and its delivery adapted to your needs, would you be interested?*

In addition academics in the LTSN Maths, Stats & OR Network were asked the following specific questions:

- *Do you teach students whose degrees are principally mathematics or is the mathematics for support teaching?*
- *With respect to service teaching, please list which departments or subjects you are service teaching for.*

There was also one question specific to the physical science and materials communities:

- *Does your department conduct mathematics teaching?*

Analysis of Questions

Do you use diagnostic testing to assess student preparedness/ability/knowledge?

	Percentage
Yes	68%
No	26%
(blank)	5%
Some	1%

68% of responders do use diagnostic testing of some kind to assess student preparedness/ability/knowledge. The extent and nature of the use of diagnostic testing does vary amongst institutions and different methods are often used for different courses.

If a test is used then is it: paper-based or computer-based?

Of those that use diagnostic testing of some kind, paper-based testing is the most common. Some departments use both computer and paper-based tests, often for different courses.

	Percentage
Paper	64%
Computer	28%
Both	8%

If computer-based, which package?

In-house computer packages appear to be the most popular diagnostic approach. DIAGNOSYS and Mathletics are the most popular of the question banks and Question Mark the most popular authoring package.

Computer Packages	Responses
In-house	9
DIAGNOSYS	7
Question Mark Perception	4
Mathletics	2
AIM	1
CALMAT	1
Maple/Mathematica	1
Teach & Learn	1
THINKS	1
WebCT	1

In what way are the results of the test used or followed up?

Approximately 70% of responders provided feedback. Of those that did, only 2 respondents indicated that nothing was done with the results. In the majority of cases the results were used to determine the level of help for the students and the results were either provided as feedback to students, provided to tutors for monitoring, or used to determine how the course syllabus would be taught.

The most common methods of follow up are:

- Maths surgeries
- Extra tutorials

Other uses include:

- Advice to use self-help software
- Monitoring
- Provision of recommended texts
- Advice on alternative course/modules

Does your department prepare first year students prior to their arrival at university with regard to their mathematical skills, or general skills?

	Percentage
No	41%
Yes	27%
(blank)	27%
Some	5%

27% indicated that their students are given preparatory material, however 41% of the respondents indicated that students are not prepared prior to arrival at university. Of those that do receive assistance the extent of the preparation varies and is often only available to certain courses.

Preparation material used includes:

- Booklets including in-house revision booklets
- Algebra and Calculus Refresher Booklet from the LTSN Maths, Stats & OR Network
- Small test for feedback at interview
- List of course topics
- Summer school
- Worksheets
- Anonymous tests

If a tried and tested diagnostic test was made available and its delivery adapted to your needs, would you be interested?

- 72% of all responders indicated a positive response.
- 49% of respondents indicated that they would be interested and a further 23% indicated that they possibly may be interested.
- 18% said that they would not be interested.

The reasons for this disinterest include:

- Already happy with current software.
- Happy with simple in house system which has been in place for years which allows for monitoring.

Do you teach students whose degrees are principally mathematics or is the mathematics for support teaching?
LTSN Maths, Stats & OR Network only

The majority of respondents from the LTSN Maths, Stats & OR Network provide both mathematics and support teaching.

	Total	Percentage
Both	39	62%
Maths	11	18%
Support	9	14%
(blank)	4	6%

With respect to service teaching, please list which departments or subjects you are service teaching for?
LTSN Maths, Stats & OR Network only

The departments/subjects varied considerably with 63 different responses including the expected scientific and business type disciplines and the not so common such as art and design and nursing.

In summary the top 15 serviced departments/subjects are:

Department/Subject	Responses
Engineering	25
Computing	22
Business	14
Physics	14
Chemistry	12
Biology	8
Economics	7
Science	7
Environmental	6
Psychology	6
Business School	5
Applied Science	4
Geology	4
Health and Community Studies	4
Management	4

Does your department conduct mathematics teaching?
Physical Sciences/Materials only

87% of the responses from Physical Sciences/Material Education departments conduct mathematics teaching of some kind.

	Total	Percentage
Yes	26	87%
No	3	10%
Some	1	3%

Conclusion

Diagnostic testing provides a positive approach to a situation. For the student it provides a constructive method, which leads to ongoing support, and for the academic it is an indication of "what is needed" in terms of teaching and curriculum changes. As the number of institutions implementing these tests increases it is becoming an integral part of mathematical education for first year students.

References

[1] *Measuring the Mathematics Problem*, Engineering Council, June 2000.

[2] *After The Diagnostic Test – what next?* Interim Report of a Maths Project Funded by the LTSN Maths, Stats & OR Network, 1(3), Lawson, D., Halpin, M., and Croft, A., August (2001).

[3] *Algebra Refresher*, LTSN Maths, Stats & OR Network, October 2001.

[4] *Calculus Refresher*, LTSN Maths, Stats & OR Network, May 2002.

The Academic Perspective

Mathletics Diagnostic Tests

Martin Greenhow ▪ Department of Mathematical Sciences ▪ Brunel University

Introduction

The Mathletics suite of stand-alone or LAN-delivered objective tests now comprises some 4600 questions spanning 175 different skills areas from GCSE to level 1 university mathematics. Much use is made of multi-choice questions where sensible, but the incorrect use of rules leads to a wrong choice being made. This means that highly-focused feedback can often tell a student not just that they are wrong, but why, see [1]. Different question libraries can be used alone (e.g. a sine rule "track and field" test); or in combinations, such as an algebra pentathlon, calculus marathon, or in diagnostic tests spanning a wider range of skills at an assumed Higher Education (HE) entry level (post-GCSE or post A-Level mathematics).

The Mathletics resource can be used in both formative and summative modes – for detailed results for various student cohorts and comparison with unseen written examination marks see [2]. Many students are assessment driven, and this has led to (easily created) bespoke tests for mathematics modules taken by maths students and those of other departments. Formative and group learning is encouraged by including each student's best ever mark for a test in their overall module mark (but the student may still be required to pass the unseen written exam at the end of the module). More recently, the resource has been used to provide remedial courses for engineering and computer science students lacking fluent GCSE maths skills.

Content

- **NUMBERS:** General Arithmetic, Arithmetic Models, Terminology, Decimals & Scientific Notation, Fractions, Power of Numbers, Percentages, Numerical Sequences, Units and Dimensions, Surds, General Complex Numbers, Add Complex, Multiply and Divide Complex, Argand diagram, Complex Polynomials, DeMoivre, Definitions and Notation, Divisibility and Prime Numbers, Euclidean Algorithm, Modular Arithmetic, U(n) Groups 1 & 2.
- **PROBABILITY & STATISTICS:** Basic Probability, Combinations, Permutations, Probability Trees, Data Types, Data Display, Analysis of Data, Shapes of Data, Definitions of Measure, Measures of Location, Measures of Dispersion, Correlation, Binomial Distribution, Cumulative Binomial Distribution, Poisson Distribution, Cumulative Poisson Distribution, Normal Distribution 1 & 2, Central Limit Theorem, Confidence Intervals, Hypothesis Testing 1, 2 & 3, Basic Queuing, Little's Laws
- **ALGEBRA:** Proportionality, Linear Equations, Modelling, Co-ordinates, Sequences 1 & 2, Expanding Brackets, Factorisation, Flow Charts, Rearranging Equations, Indices 1 & 2, Simplification, Solving Equations, Using Formulae, APs, GPs, Sigma Notation, Completing the Square, Inequalities, Simultaneous Equations, Growth/Decay, Pascal Triangle, Binomial Theorem, Polynomial Multiplication, Polynomial Division, Min/Max of Quadratics, Partial Fractions 1 & 2.
- **FUNCTIONS:** Recognising Graphs, Limits of Functions, Domains and Ranges 1 & 2, Inverse Functions, Function Manipulation, Symmetry of Functions, Degrees <> Radians, Trigonometry Definitions, Special Trigonometry Values, Trigonometry Equations 1 & 2, Trigonometry Graphs 1 & 2, Reciprocal Trigonometry Functions, Sine Rule, Cosine Rule, Combining Signals, General Trigonometry Solutions, Trigonometry Identities, Logarithms and Exponentials.
- **DIFFERENTIATION:** General Differentiation, Differentiation of Powers, Differentiation of Products, Differentiation of Quotients, Chain Rule, Differentiation of Logarithms and Exponentials, Differentiation of Trigonometry, Differentiation of Hyperbolics, Differentiation of Inverse Trig., Differentiation of Inverse Hyperbolics, Logarithmic differentiation, Parametric Differentiation, Implicit Differentiation Series & Expansions, Differentiation of Functions of two variables.
- **INTEGRATION:** Integration of Polynomials, Integration of Algebraic Functions, Integration of Rational Functions, Integration of Trigonometry Functions, Integration of Hyperbolic Functions, Integration by Substitution, Integration by Partial Fractions 1 & 2, Integration by Parts 1 & 2, Double Integration, ODEs: First Order Integrating Factors 1, 2 & 3, First Order Solution by Integrating Factors with bc's, First order Separable 1, 2, 3, First Order Solution by Separation with bc's, Second Order Complementary Function, Second Order Particular Integral, Second BVP, Second Order Classification
- **LAPLACE TRANSFORMS:** Basic Laplace Transforms 1 & 2, First Shift Theorem, Inverse Laplace Transforms and Applications to ODEs.
- **NUMERICAL METHODS:** Initial Conditions and Notation, Taylor Series for ODEs, Second, Third and Fourth Order Runge Kutta, Pivoted Systems.
- **STATICS:** Loaded Beams, Resolving Forces, Pivoted Systems
- **VECTORS & MATRICES:** General Vector, Vector Addition, Dot and Cross Products, Triple Products, Lines and Planes, 2x2 and 3x3 Numeric and Algebraic Determinants, Applications of Determinants, Matrix Addition and Scalar Multiplication, Matrix Multiplication, Inverse Matrix, Non-Square Systems, Translation, Rotation and Shear, 2x2 and 3x3 Eigenvalues and Eigenvectors
- **GRAPH THEORY:** Basics, Digraphs, Colourings, Networks, Paths and Walks 1 & 2.

Participants

Increasingly, Mathletics has become a workhorse of our teaching at Brunel University; in the 1999/2000 academic year some 600 foundation, mathematics, engineering and biological sciences students took over 23,000 diagnostic and continual assessment tests, whilst for 2000/01 the tally was 25,000. This year (2002/03) about 300 students took diagnostic tests in freshers' week.

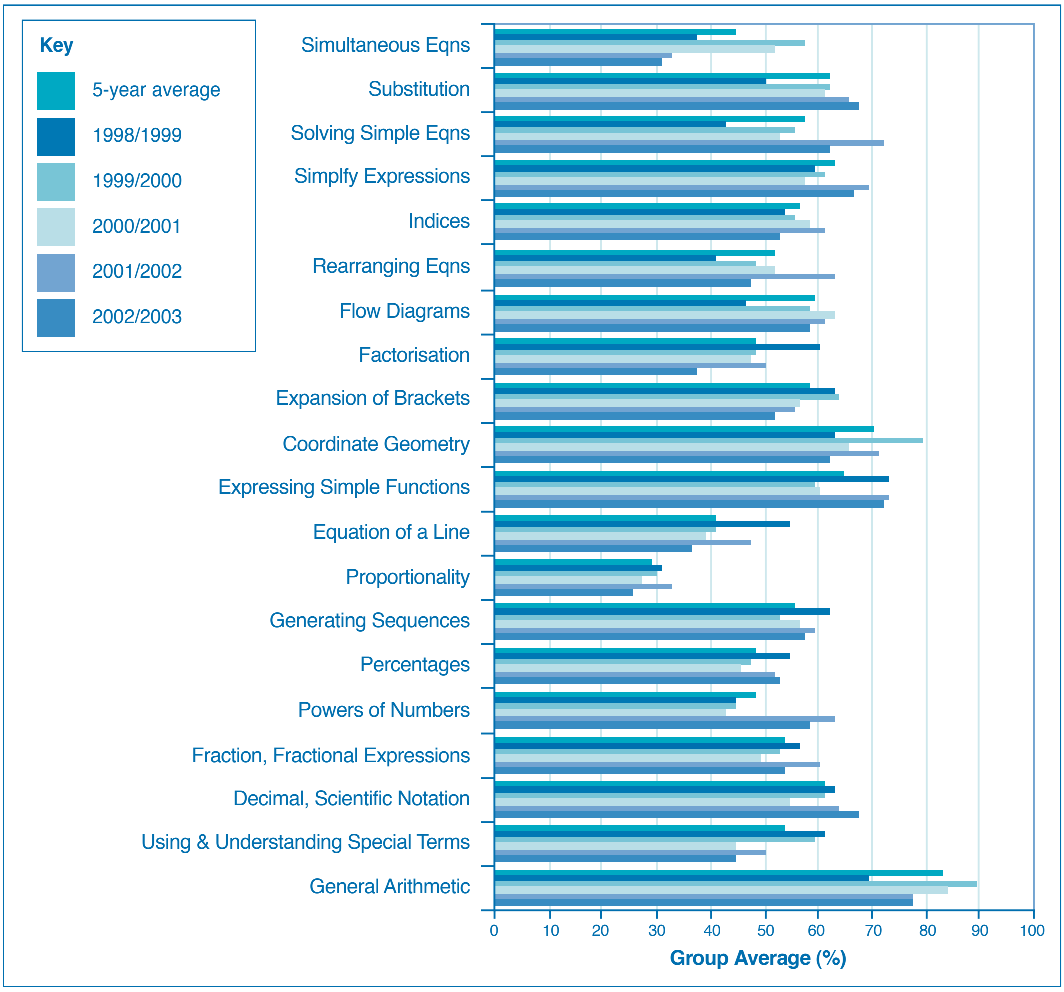

Figure 1: Zero Level Diagnostic Tests 1998/2003 – Year-on-year group averages for Foundation Students. Updated from [2].

The current snapshot (taken November 2002) is typical; level 1 undergraduates in mathematics have just completed a calculus test and are about to start one on linear algebra; systems engineers are mid-way through a set of tests, whilst Biologists and Foundations of Science, IT and Engineering have completed an extensive set of algebra tests and are starting a similar set on functions and (polynomial) calculus. About six maths staff are involved, two of whom manage all the answer files.

Much of this activity takes place during students' free time, but some happens in staffed workshops. The teaching dynamic is interesting here; staff are able to jump in when a student has questions and teach alongside the student. This results in the lecturer being on the same side as the student, physically and metaphorically, so it's "us against the PC" rather than "staff versus student". Since the student is also focused on the problem, this makes for extremely effective learning.

Feedback to Students/Staff

Diagnostic tests are followed-up with emails to each student/student tutor with results and advice. Discussions often result in students revising or learning material and retaking the test. Equally important is the whole class view of first years skills, which informs level 1 lecturers and admissions tutors. An advantage of CAL is the speed and comparative ease with which large amounts of data can be interpreted in a useful (actionable) way, see Figure 1.

Dissemination/Developments

Mathletics is available free on request and about 120 universities and colleges in the UK have already been sent a copy. Given the blurred division between school and university mathematics, much of the above content has been explicitly linked to GCSE, A/S-Level and A-Level topics and repackaged as "Mathletics for schools". Again this (free) resource is proving popular.

[3] describes recent technical developments to a web-based version of Mathletics, such as dynamic questions and diagrams that change according to random parameters chosen at runtime.

References

[1] *Setting Objective Tests in Mathematics with QM Designer*, Maths, Stats & OR, February, Greenhow, M. (2000).

[2] *Answer Files – what more do they reveal?* LTSN Maths, Stats & OR Network, CAA Series http://ltsn.mathstore.ac.uk/articles/maths-caa-series/jan2002/index.shtml, Greenhow, M. (2002).

[3] *Using Question Mark Perception v3 for Testing Mathematics*, MSOR Connections 2(3): August, Greenhow, M. and Nichols, D. (2002).

Diagnostic Testing and Student Support

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Abstract

Students on Engineering awards at UWE come from a range of academic backgrounds that include A2/AS-Level, B-TEC, Foundation year, overseas qualifications and mature students who in some cases are returning to education after an absence of over ten years. Ensuring that individuals from such a diverse population can develop the necessary mathematical skills and knowledge to cope with the demands of an Engineering award is clearly difficult. In this case study we describe the development of diagnostic testing at UWE and its role in a strategy for teaching mathematics to a large mixed ability group.

The Execution

A. Paper-based diagnostic tests (1992-97)

A paper-based multiple-choice test was designed to test basic knowledge of algebra, trigonometry and elementary calculus. The test was taken by students during induction week and was marked in time for results to be distributed during the first week of term. Students with substantial difficulty in a topic were referred to a Mathematics and Statistics Learning Centre for additional tutoring.

The system was inexpensive to set up and administer and provided feedback to both students and tutors together with a mechanism for acting on the information. Initially the system worked well but with each year the proportion of students demonstrating substantial weaknesses increased, until it became difficult to manage the follow-up support.

Student reaction to being tested at the beginning of the course was quite negative. The paper-based diagnostic test only offered students one attempt. Students did not have time to “prepare” for the test resulting in unease amongst some that they did not “do themselves justice” and by inference throwing some doubt over the usefulness of the information received. Many students did not participate in the remedial activity designed to address their real or perceived weaknesses. It was clear that in this format the diagnostic test did not necessarily give a realistic picture of an individual’s level of understanding and how they should subsequently organise their study.

Paper-based diagnostic testing was abandoned because it had ceased to make a positive contribution to the delivery of the module. In the period between the abandonment of the paper-based system and the introduction of computer-based diagnostic tests, a greater amount of time was given to the revision of basic techniques of algebraic manipulation, solving equations, trigonometry and calculus. In resource terms this was achieved by increasing the lecture time for each student from a single hour to two hours each week. Tutorials continued to be for one hour each week to a group of 20-24 students and resources given to the Mathematics and Statistics Learning Centre were increased so that it was staffed for one hour each day.

B. Computer-based diagnostic tests

Diagnostic tests were re-introduced for first year engineering students at the beginning of this academic year. Students take four computer-based tests in algebra, equations, trigonometry and elementary calculus with three attempts at each test. Each test should take between thirty minutes to one hour to complete depending on the ability of the student. Students must complete the tests by the end of the second week of term and are given instant feedback as to their score. A different test (but of the same standard) is taken at each attempt. The diagnostic tests form the first stage of a support mechanism for the module which is summarised below.

The delivery of the module is as described in the previous section. Follow-up support to the diagnostic tests is initially managed through contact with students in tutorials. Students with significant problems are then offered one-to-one support by the tutor or through the Mathematics and Statistics Learning Centre. Material on the module is organised into four blocks with a computer-based test held at the end of each block (note that there is also an end of module examination). The test is open for two weeks and students are permitted three attempts. Having identified areas of difficulty, students can seek assistance during each test period from their tutor. After each test, workshops are held for students who still feel they require assistance with certain topics. Hence, students and tutors are being made aware at each stage where problems are occurring and the support offered can build upon the work already carried out by the student.

Results

It is clearly too early to comment on the success or otherwise of the diagnostic tests in this course. However, some initial data is given below.

The average test scores for the four diagnostic tests are shown in table 1. The average scores for algebra and equations are much higher than the scores for trigonometry and calculus. This is not surprising as the calculus and trigonometry tests involve a higher level of manipulation than the algebra and equation tests.

The average scores for the first two computer-based assessments for the module are shown in table 2. The “Algebra and Functions Test” combines transposition of formulae, equations, trigonometric functions and other topics such as partial fractions and complex numbers that were not in any of the diagnostic tests.

Table 1: Diagnostic Test Statistics

Diagnostic Test	Mean (%)	Median (%)
Algebra	67	74
Equations	61	68
Trigonometry	34	30
Calculus	40	39

Table 2: Assessment Test Statistics

Assessment Test	Mean (%)	Median (%)
Algebra and Functions	69	73
Calculus	64	68

The "Calculus Test" consists of standard rules of differentiation and integration, including integration by parts and parametric differentiation, and again includes material beyond the level covered in the initial diagnostic test. The test scores suggest that the majority of students have either maintained or improved their level of performance since the beginning of the course. Clearly, we would have expected performance to improve once the course was underway.

One of the aims of the overall support developed for this module is to manage the different needs of the quite different groups taking the module. One of the benefits of the computer-based delivery of both the diagnostic tests and the assessment is that it creates a mechanism for monitoring the progress of students that is reasonably efficient in staff resources.

The Barriers

A. Student confidence and participation

Our experience of student reaction to computer-based assessment has consistently been positive. The system used is user friendly, very flexible and is intended to help students structure their study. The computer-based diagnostic tests were also well received by the students. In contrast to the paper-based tests used in previous years, students were much more willing to accept the rationale for the diagnostic testing. The multiple attempts meant that students felt that they were able to demonstrate their knowledge of the topics.

B. Development cost

The computer-based diagnostic testing at UWE has been developed out of a Computer Assisted Assessment (CAA) programme that started in 1998 in the school of Mathematical Sciences. Hence, in this instance we were able to make use of a great deal of material that had already been developed and quality tested. Other material was imported from the Mathletics CD-ROM [1]. However, it should be noted that considerable staff time is required to set up the initial question bank.

C. Technical issues

The CAA system adopted at UWE is QuestionMark Perception. While authoring and analysis of results is reasonably straightforward, there are issues to be considered of management of the question bank database and generating participant login names and passwords in an efficient manner, especially as the use of the system has increased. We currently assess of the order of 800 students using this system. Typically each student will sit between two and four tests with two or three attempts at each test. It is therefore essential to have good in house IT support.

The Enablers

Computer-based assessment and diagnostic testing have been developed at UWE as a result of

- initial support provided by the Faculty for the development of the CAA programme
- colleagues within the school of Mathematical Sciences generating the majority of the questions
- use of freely available questions from resources such as Mathletics.
- dedicated technical support for managing the software and the question database.

How Can Other Academics Reproduce This?

- Computer aided testing is expensive to set up in terms of staff effort. Some institutional support and leadership is required to free up staff time and to encourage sharing the workload among academic staff.
- The cost of development can be reduced by making use of existing resources and experience. In this respect, the LTSN is a useful body to provide relevant contacts.
- There must be an effective mechanism in place for acting on the information provided by the diagnostic test.

Quality Assurance

As far as the tests are concerned, questions are internally moderated for both accuracy and standard. In addition to this, the results from the diagnostic tests are clearly of interest to other processes operating in the faculty such as admissions and student support. Apart from the support we have set up on the module, these wider connections have yet to be developed.

Other Recommendations

- Prospective students could use the tests with revision material, to prepare themselves for their course prior to their arrival at the university.
- Diagnostic test results can be compared against material covered in specific A-Level modules to gain a more informed view of the potential strengths and weaknesses of students with a particular profile of A-Level results considered on a module by module basis.

Reference

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Using Mathematics Diagnostic Testing on Engineering Courses

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Abstract

Even as long ago as the mid-1990s, a survey for the Open Learning Foundation [1] found that most universities were using some form of mathematics diagnostic testing on their first-year undergraduates, usually during Induction Week. With the advent of computer-aided mathematics diagnostic systems such as DIAGNOSYS [2], it has become easier to obtain an off-the-shelf diagnostic system. Even so, many people still use their own in-house tests. This study considers one such example.

The Execution

This case study relates to a paper-based diagnostic test that has been in use unchanged since the early 1990s. Originally written as a computer-based test using Question Mark software, it was soon found that network problems, an insufficient number of PCs and student reluctance to use computer-based testing forced the author to transcribe the questions into a paper-based test.

The in-class, 40 question, multiple-choice test is given to *all* design and electronics undergraduates during their induction week. Although the test is not officially time-limited (so helping to relieve student anxiety with respect to timed tests), all students invariably finish within 30 to 90 minutes.

Some of the students have A-Level Mathematics, although most do not. Even so, the content of the test is unashamedly pitched at GCSE level since, for many, it is the underlying basic mathematics (algebra, in particular) that is the major problem. An A-Level in Mathematics is no guarantee that a student will pass the diagnostic test (or the more student-friendly, 'quiz', as it is euphemistically known).

Examples of questions and post-test student feedback and analysis can be found in references [3] - [6]. All students use a 'tick the box' sheet for their answers. Solutions on a transparent overlay allow the tests to be marked rapidly – usually by the time all students have left the room. Optical character recognition would be a better way of marking since this would also facilitate a more comprehensive analysis of the students' responses; this is a future refinement.

The test is in sections, including numeracy, algebra, and geometry. Students who gain a good overall score but who do not perform well in particular sections are given directed reading to help in these weaker areas. Usually this is in the form of handouts with some explanatory text, examples and exercises. An 'open door' policy on the lecturer's part ensures that students can discuss these exercises and have their solutions checked if needed. However, for students who do not achieve an overall 50% score on the Diagnostic Test, the main help comes from a set of one-hour-per-week 'Extra Maths' classes. These are run in parallel with the students' main lectures throughout the session and each usually takes the form of an approximate 20-minute discussion followed by exercises for the students to complete. Care has to be taken here that students are not stigmatised by having to attend – some even have to be dissuaded from speaking of these classes in terms of "Maths for Dummies". This is not a major problem, however, since the Extra Maths classes can contain a large proportion of the total student cohort. A register is taken each session for all those who obtain a test score of less than 50%. Students obtaining between 50 and 60 are 'recommended' to attend, but do not have to, and those who score more than 60 do not have to attend, but can do so if they wish. The topic for Extra Maths is usually announced during the week's main lectures and often covers topics chosen by the students themselves.

Possible Barriers

Departments have to agree to their students undertaking a mathematics test in Freshers' Week. Fortunately, since the test's aim is to direct extra support to students who may otherwise be lost at the end of the first year due to failure in analytical subjects, this is not too great a problem. A diagnostic test on its own does nothing to help weaker students. Follow-up support is needed and here it is imperative to convince serviced departments that they should finance this extra support – in our case, for a one extra hour per week class. Again, this should not be a problem since, when put in financial terms, it only needs half a dozen students to be 'saved' and the scheme recoups all expenses.

Unfortunately, diagnostic testing and comprehensive follow-up support can fall foul of its own success. The whole process can encourage a dependency culture in which students are not willing to help themselves. What has to be borne in mind, however, is that the diagnostic/follow-up combination is used, amongst other things, to tease out those students for whom learning mathematics may already have been an unpleasant experience and for whom further mathematical study may be a daunting prospect. When bearing in mind, also, that these students are quite often excellent independent learners with respect to their 'main' engineering subjects, then a sympathetic approach to spoon-feeding in basic mathematics can be tolerated.

Quality Assurance

There are a variety of mechanisms that elicit feedback from students including representation on course teams and departmental and school committees. However the most telling feedback is that obtained from student/course tutor interaction and from the teaching and learning assessment forms that all students have to complete both during and at the end of each academic year. Feedback is invariably positive.

Evidence of Success

There is no way of counting the number of students who *may* have failed if they had not undertaken the test/support combination outlined here. However, various correlations have been analysed [5]. For example, there was found to be no significant correlation between the students' diagnostic scores and their end-of-year results in analytical subjects. This is fortunate, since a significant (positive) correlation here would show that a weak student on entry was still weak at the end of the year, i.e. the support provided had not added any value. The strongest correlation found is between Extra Maths attendance and students' end-of-year results in their main (analytical) subjects. The friendly approach adopted in these classes and the extra time that can be taken to explain fundamentals shows that the selection via the diagnostic test and subsequent follow-up support is a successful combination. Another indicator of success is that each year, continuing students are disappointed to find that Extra Maths is not provided in their second year of study. It is also interesting to note here that some of the students who score more than 60% also attend regularly.

Recommendations

- With the current eclectic mix in the background and abilities of current students, all courses in which mathematics is a non-specialist subject should use diagnostic testing on entry.
- Further, it is recommended, though not mandatory, that content should be set at GCSE level in order to ensure fundamental mathematics is sound. (There is no point in students trying to use partial fractions, for example, when they cannot even handle numerical fractions.)
- Even students entering Mathematics degree courses can benefit, albeit from a higher-level test.
- Point out to whomsoever, that diagnostic testing (and follow-up support) can help student retention and hence save money.
- Computer diagnostic testing is already available in the form of DIAGNOSYS. If you have the computing resources, this is the easiest route to take. If not, a paper-based multiple-choice test is the easiest to mark (although perhaps time consuming to produce if it is to have meaningful distractor answers).
- The use of meaningful distractors (e.g. 1/3 + 2/5 = 3/8) can highlight misconceptions that can be specifically addressed in the Extra Maths sessions.
- Use an 'I don't know' option for every question. Encouraging students to use this when they do not know the answer will inform you where specific support is needed.
- For paper tests, keep the question sheets and the tick-the-box answer sheets separate. That way the question papers can be used in successive years, so reducing printing costs.
- Students are 'fragile' in Week 1. Let them know that the results of the test go no further than your desktop, and that the marks will not be used in any summative way.
- Test students on what they know, not on how quickly they can answer a test – allow a two-hour slot, say, if you are using what you consider to be a one-hour test.
- Further recommendations can be found throughout reference [1].

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Diagnosis of Mathematical Skills Among Bioscience Entrants

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Abstract

A paper-based diagnostic test of mathematical skills, presented to Stage 1 undergraduates, revealed that entrants encounter difficulties with some of the basic mathematical concepts that are essential if students are to successfully complete a programme of study within the biosciences. Students reacted favourably towards a number of computer-based learning materials aimed at supporting development of their basic mathematical skills through self-directed learning. However, the availability of such resources made no significant difference to the students' overall performance in a subsequent test. Some issues and applications are discussed.

The Execution

In the autumn of 2001 the School of Biology and Biochemistry introduced a *'Skills in Biosciences'* module for all its Stage 1 undergraduate students (approximately 125). The introduction of this module was in part to facilitate implementation of Queen's University's Student Skills Policy, but more importantly it was an attempt to ensure that all first-year entrants, who increasingly exhibit a wide diversity of entrance qualifications, had a common foundation in a range of key skills (including communication, numerical, ICT, problem-solving and team-working), as well as practical bioscience and career management skills.

Entrants possess a wide diversity of mathematics qualifications, ranging from grade C at GCSE level to grade A at A2-Level. Within the 'numerical skills' component of this 'skills' module, two 1-hour lectures and a 3-hour practical class are devoted to highlighting the importance of numerical skills within a bioscience context, explaining some of the more basic mathematical concepts and providing students with an opportunity to further develop and practise their numerical skills. In the first of two lectures, following a brief introduction on why numerical skills are important and an explanation of the characteristics that define a numerate individual [1], students are asked to complete a 30-minute paper-based practice test of their basic mathematical skills and knowledge (see Example of Paper-Based Diagnostic Test, p15), *without* the aid of a calculator. This test is marked and returned to students at the start of their practical class in the following week, but marks do not contribute towards their final module mark. In the second lecture, contextual examples are provided of some of the mathematical concepts students must understand, but with which many often experience difficulties, e.g. using measuring scales and SI units, manipulating equations, logarithms, power expressions and scientific notation.

The following week, students have a 3-hour practical class, during which they are asked to access, use and evaluate four computer-based learning (CBL) resources that can provide them with help in diagnosing, further developing and/or practising their numerical skills. Students are able to use the results of the practice test to help them identify their personal strengths and address their weaknesses. The resources include: (i) the 'Working with Numbers' section of *Key Skills Online* (intranet support for students available from Gower Publishing), (ii) *Maths for Microbiology* (a Question Mark CBL tutorial developed by Fiona McGartland in collaboration with the author and accessible via Queen's intranet), (iii) *Numbers Count* (a prototype web site currently under development by the author and specifically aimed at supporting the basic mathematical skills covered in Stage 1). The fourth resource is selected from a list of additional, 'maths' web sites.

One week after the practical class, students sit a second, assessed test, which is similar in structure to the practice test and which once again does not allow the use of calculators; marks from this test contribute 4% towards a student's final module mark. In addition, students face ten similar questions in the module examination in January (where the use of calculators is permitted).

Results

The purpose of the tests is two-fold. Firstly, to collect data on the basic mathematical skills and skills deficits of entrants, and secondly to inform students about their mathematical abilities at the start of their undergraduate experience and provide them with the opportunity to address any weaknesses early in their course of study. Figure 1 summarises the results of the practice and assessed tests held in 2002. It illustrates that a relatively high proportion (i.e.>50%) of students encountered difficulties with those questions requiring an understanding of (i) fractions (nos.3 and 4), (ii) logarithms (nos.11 and 12), problems involving conversions between units of measurement (nos.13 and 14), and (iv) SI units (nos.17-20).

Although there was no significant difference between the mean marks out of twenty (10.4 and 10.9 correct answers respectively) for the two tests ($t = -0.85$, $df = 219$, $p = 0.4$), the lowest scores were 2/20 and 3/20 and only 2 (2%) and 1 (1%) student respectively answered all twenty questions correctly. The percentages of students exhibiting an increase, decrease or no change in marks following the second test were 49% (mean increase in marks = 17%), 37% (mean decrease in marks = 12%) and 14% respectively. There was a significant positive correlation between students' mean scores in the two tests and their GCSE, AS-, or A2-Level grades in mathematics ($r = 0.679$, $df = 116$, $p < 0.001$). The percentages of students possessing GCSE, AS-Level or A2-Level as their highest qualification in mathematics were 66%, 8% and 26% respectively. The results presented support those of an earlier study, which used a similar diagnostic test [2].

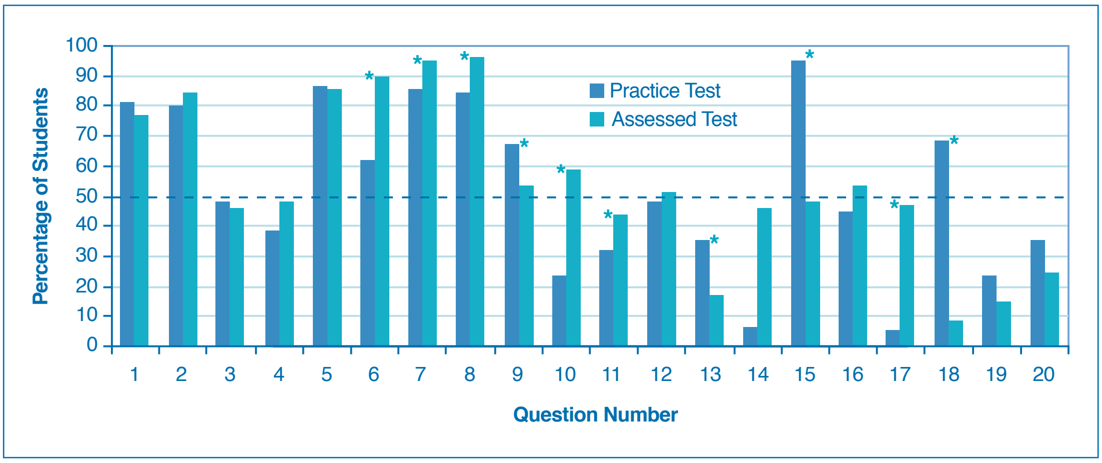

Figure 1: *Percentage of students in 2002 who provided correct answers to the 20 basic mathematics questions illustrated in the Appendix. * Significant differences between the practice (n = 109) and assessed (n = 118) tests* ($\chi^2 \geq 4.0$, $df = 1$, $p < 0.05$).

Issues

Among the main issues to emerge from the use of this and similar diagnostic tests is the students' lack of confidence and, in some cases, almost fear of anything numerical. Many fail to appreciate the importance of numerical skills, not only within their elected academic discipline, but also in selection procedures used by employers, their future profession, as well as in their everyday lives, and their reliance on calculators for even the simplest procedure is alarming. The introduction to and availability of CBL resources appeared to have little effect in improving the students' mathematical skills. There are several possible reasons for this, including insufficient time prior to the second test, as well as students' reluctance to assume responsibility for their own learning. A number of alternative strategies may be directed towards improving entrants' numerical skills [3]. In future years it may prove necessary to 'stream' students on the basis of results from the practice test and offer staff-led, small-group tutorial/workshop sessions at which the specific concerns and skills deficits of individual students may be addressed more directly.

Applications Across Academic Disciplines

Such paper-based diagnostic tests are relatively easy to prepare and assess, even when dealing with relatively large numbers of students, and the calculations included can be tailored to the specific requirements of an academic discipline. Alternatively, if there is little opportunity or requirement for the development of basic numerical skills within a particular discipline (e.g. English), and the primary purpose of such tests is to prepare graduates for the employer selection procedures they may encounter, a variety of numerical tests are commercially available (e.g. from Saville and Holdsworth Limited).

The experiences described are informing the development of teaching and learning strategies, not only in the School of Biology and Biochemistry, but also across Queen's University. For example, work is in progress to develop a model for the diagnosis and support of basic numerical skills among arts and humanities students, with a view to better preparing them for the numerical skills tests employers are increasingly using as part of their graduate recruitment procedures.

Example of the Paper-Based Diagnostic Test

Stage 1 undergraduate students were asked to attempt (without the aid of a calculator) in Autumn 2002.

1. 45.92 + 32.76 + 3.33 – 9.76
2. (2.8 + 9.2 – 3.1) x (12 + 38)
3. 4267/9 *(present your answer as a decimal to 3 places)*
4. 5/6 x 4/5 *(present your answer as a decimal to 3 places)*
5. 12% of 4000
6. Decrease 63 by 20%
7. In the following series which number has the smallest value?
   0.1298 1.298×10^{-3} 12.98×10^{-1} 1.298×10^{-2} 129.8×10^{-4}
8. In the following series which number has the largest value?
   3.539×10^{6} 3539 0.3539×10^{7} 353.9×10^{4} 35390×10^{3}
9. $(5.5 \times 10^{2}) + (3.5 \times 10^{-2})$ *(present your answer in standard form)*
10. $(0.5 \times 10^{5}) \times (5 \times 10^{3})$ *(present your answer in standard form)*
11. $\text{Log}_3\ 81$
12. $\text{Log}_{10}\ (10^{5} \times 0.001)$
13. The mean weight of a mouse is 25g. If there are 100 mice per hectare calculate the biomass of mice in a square kilometre. Present your answer in $kgkm^{-2}$.
14. A good hay crop will yield 100 bales per hectare, weighing an average of 200 kg each. What area of land (in km^2) would yield 4×10^6 kg of hay?
15. If $y = \log_{10}(x + 1) - 0.25^{-1}$ what is the value of y when x is 9999
16. Transpose and simplify the following equation to make x the subject: y = (x - 6) - 2
17. What is the SI base unit for amount of substance?
18. What is the definition of a pascal in SI base units?
19. What is the prefix for 10^9 in SI units?
20. What is the prefix for 10^{15} in SI units?

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Historical Study of Correlation between A-Level Grades and Subsequent Performance

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Abstract

The subject of A-Level mathematics has attracted a great deal of political and academic controversy. Those who represent the academic community in Higher Education have argued for over a decade that the standards of A-Level mathematics have been declining and continue to do so. Elsewhere it has been argued that much of the decline perceived by those who teach in engineering and science departments is more likely to be attributed to the very substantial national decline in entry standards to engineering and science courses rather than any real change in A-Level standards. Using available statistics, a study of the electronics students at York set out to discover whether these questions could be answered and the results were published in a detailed paper [1] of which the following is a summary.

Introduction

Those who argue about mathematics standards or for that matter any other facet of the national assessment system often have very different views as to the purpose of the assessment. Any A-Level can be seen as an award that certifies that a particular curriculum has been satisfactorily completed, or it can be regarded by Universities as a measure of particular skills and knowledge that are essential to further study in the student's chosen subject area.

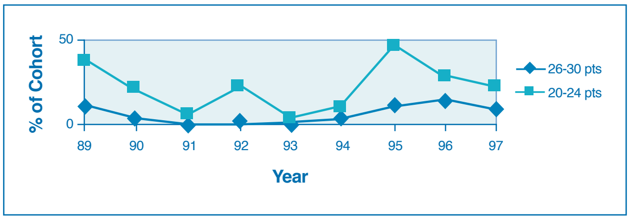
Using available statistics, a study of the electronics students at York set out to discover whether these questions could be answered:

1. ***Given that grades at A-Level are used heavily as a tool for selection do they remain a reliable indicator of ability?***
2. ***For the same grades: is a student today any less well prepared to cope with the academic demands of our courses than a decade ago?***

Whether a student passes or fails their first year depends on a number of factors including progression rules, transfer to a different course, personal circumstances etc ("failure" is taken to mean that the student has obtained a year end overall mark of less than 40%). By 1989 in the Department of Electronics at York failure rates had reached alarming proportions, mathematics was identified as a major contributing factor and there were major revisions in teaching provision in 1990, 91 and 92. Finally in 1993 substantial reductions in both the content of the first year course led to corresponding changes in mathematically demanding courses. These steps appeared to have succeeded in 93 and 94 but there has been a steady deterioration up to the present day. Graph 1 shows failures as a percentage of the cohort for two groups of students – those who obtained better than BBB (24 points) at A-Level and those who obtained a grade between BBB and BCC (20 points) inclusive – throughout this period of change.

The dip in the graph at 1995 was the result of the department experimenting unsuccessfully with a radically different approach. The subsequent years of 1996-98 reverted back to similar academic content and standards as those used in 1993-94. Over these five years the failure rate amongst the weaker group (20 to 24 pts) had moved from zero to the unacceptable level of around 25%! Even amongst the best group (better than BBB) the level of failures had escalated from zero in 1993 to 6-13%.

Graph 1: Part 1 Failure



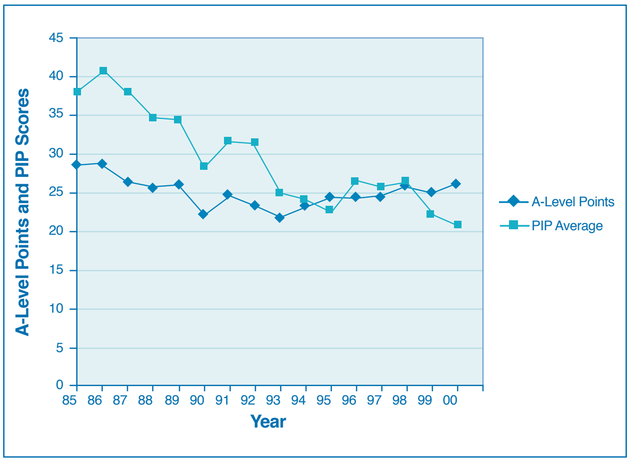
The Entry Test

We are naturally testing the ability of these students against our own assessments in the department. It remains possible that the measured drift in results is an affect of our assessment process and/or teaching performance. We do however have one constant measure of their mathematical ability. In the Electronics department at the University of York, in common with many other Science and Engineering departments, we give first year students a mathematics test on their second day in the department. The purpose of the test is to give us some idea of the "quality" of our latest intake and also to highlight, for the benefit of those of us who teach first year mathematics, any areas of generic weakness that might require attention. The results are made available to supervisors who can utilise them to motivate those whose mathematical knowledge would seem to be inadequate. We have used the same test, administered in the same way for the last 15 years. Consequently, whatever its defects as a test, it does provide a consistent measure against which it might be possible to draw some conclusions.

The test we use was originally devised by the University of Cardiff as part of a project known as the Physics Interface Project (PIP) and was based on the A-Level mathematics syllabus of the early eighties. It was intended primarily as a test of knowledge with 50 multiple-choice questions to be attempted in a two-hour period. None of the questions require anything but the simplest manipulation and students are discouraged from guessing.

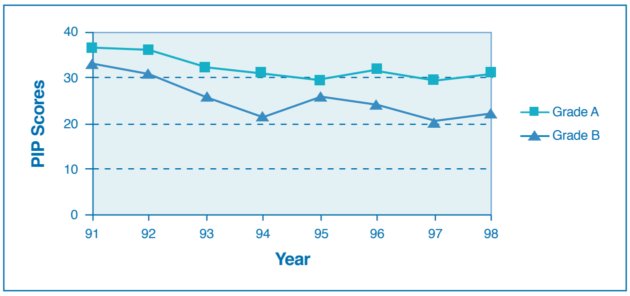
The same test has been taken under similar conditions each year and the results can be used to assess the ability of students after A-Level mathematics. However the test is open to obvious criticisms. It does not test the same skills as a conventional mathematics examination, no real insight is required; there is little requirement for complex manipulation and the student is certainly not called upon to pursue the topic through any kind of lengthy analysis. What it does test however is knowledge of a range of key facts. We have found it invaluable in exposing generic weaknesses. We have noticed for instance, over the last few years a declining ability to cope with logarithms and powers. This is clearly identifiable from the PIP test and amply confirmed in further contact with the students.

Graph 2: A-Level Points and PIP Scores



Graph 2 shows the average score for the first year cohort in the PIP test (expressed as a score out of 50) for all the years for which we have records and the average A-Level points score for the cohort. As can be seen the average score on the PIP test declines throughout the period from 39/50 to 21/50. For the first few years in which the test was used it was always assumed that the "worry line" should be drawn at 60% and that any student scoring below 60% should be advised to concentrate on mathematics revision or indeed receive special tuition. Today the bulk of the cohort fall below that line!

Graph 3: PIP Scores by A-Level Grade



Graph 3 shows average PIP test scores for students who obtained respectively A or B grades in A-Level Mathematics. It can be seen that between 1991 and 1998 the average score of a student with an A at A-Level Maths has declined slightly from a little over 35/50 to 30/50, whereas the scores of students with grade B have declined from around 31/50 to around 20/50. It should also be observed that between 1991 and 1997 the percentage of students taking Mathematics A-Level and obtaining grades A, B, or C increased from 48% to 66% with a similar increase for Physics [3].

The long term picture is very clear. A student with an A at A-Level mathematics today will, on average, obtain a score on our test which would have placed them near the bottom of the cohort fifteen years ago. Part of the decline over the fifteen-year term can be attributed to syllabus changes. Five of the fifty questions on the test demand an acquaintance with topics no longer included as core syllabi in all A-Level maths courses. Two other questions demand a basic grasp of complex numbers, but eight questions required only GCSE mathematics. It is not possible, however, to explain the year-on-year decline throughout the nineties in terms of syllabus changes.

Even if syllabus changes are taken into account it does not change the problem from the perspective of an engineering department. The PIP test was designed as a test of knowledge of a range of key facts that the student needed to know before commencing our courses. That requirement has not changed. It is deeply worrying that an average student with grade B in A-Level mathematics is only able to obtain a score on our test which is marginally better than that which could be obtained by random guessing.

Whether any sensible conclusion can be drawn is debatable but the sharp dip in both plots in 1990 coincides with the first entry of students with GCSE qualifications rather than GCE Ordinary level qualifications. A similar series of results has been published [2] using the same test for new Physics students and these results, including the 1990 dip, are remarkably similar. It is advisable to take some care with these figures. A-Level points score is a crude measure as it can include any A-Level (including General Studies). The PIP test score average includes the entire cohort and therefore, there can be a small number of students who have other qualifications.

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Diagnostic Testing within Institutions

Paper-based Test

Cardiff University

Interview with Allan Coughlin ▪ Cardiff School of Engineering

Abstract

All students are assessed using a paper-based, but optically marked, written test of 12 multi-choice questions (MCQs). The test covers algebraic simplification, approximation, logs, trigonometry and calculus. It is based on a test developed at Coventry University. It is used to assess students' strengths upon entry.

The Execution

The test was carried out in week 1 of the students' course, and took place simultaneously in two large lecture theatres. The test was invigilated and students were also asked to fill in a questionnaire survey on their attitudes to mathematics. The 12 questions covered basic algebra, logs, integration, differentiation, trigonometry and approximation. The tests were marked using an optical reader and results were reported back to students by their personal tutors. Most students do not use all the time available (nominally 50 minutes).

The Results

The results of students are fed back to their personal tutors and support classes are provided. These are based on students' degree programmes. This support is not directly linked to teaching but is part of general tutorial support.

There is perceived to have been a drop in standards over the last few years. One feature that has changed is the drift of students from pure mathematics and mechanics to pure mathematics and statistics. Other deficiencies noticed have been algebra, elementary calculus, trigonometry and complex numbers. Overall teaching has been modified to make course material more accessible to the students. This applies to mathematics material in all four years of the degree. Informal support has become formalised through a specific 'support hour' sessions in small groups (~20 students).

The Barriers

There were no serious barriers in the conducting of this kind of test. The only possible technical problem might be the optical scanning of mark sheets when students do not follow the instructions they are given.

The Enablers

Some of the help provided to students is limited in access. Records of attendance at lectures and the like are kept. A 70% attendance record is required for a student to be given access to the small group support. This encourages students to take advantage of the primary means of instruction in the department.

Quality Assurance

The appropriate professional bodies accredit all Engineering degrees. This means that external assessment/validation is in place. The tests are based on those developed by Duncan Lawson at Coventry University who is a QAA Subject Specialist Reviewer in Mathematics, and a Member of the Open Learning Foundation Mathematics Working Group (see Coventry University, p19).

Other Recommendations

Monitoring of student attendance, and restricting access to resources if attendance is poor, encourages students to take advantage of their opportunities at the time most beneficial to themselves.

Paper-based Test

Coventry University

Interview with Duncan Lawson ▪ School of Mathematical and Information Sciences

Contribution from John Danks ▪ School of Engineering

Abstract

Diagnostic testing at Coventry University encompasses various disciplines. Co-ordinated by the Maths Support Centre, the test is used to assess the students' ability and target appropriate mathematics support as early as possible. This case study reviews the testing process and how it is linked to appropriate support material, advice and learning resources.

The Execution

The mathematics department at the University of Coventry has carried out a comprehensive diagnostic test since 1991. During the first week of the academic year, 600-700 entrants to a range of science and engineering degrees and also to courses in the Business School and the School of Art and Design sit one of the Mathematics Support Centre Diagnostic Tests. There are two tests: one aimed for students on courses with an A-Level in mathematics (or equivalent) entry requirement and the other for students on courses with a GCSE mathematics entry requirement.

The Maths Support Centre, also established in 1991, manages the procedure but the tests are administered by staff of each the various participating disciplines. The test is timetabled and takes place in the host department.

Engineering students were observed in a large classroom: each was handed an OMR (Optical Mark Reader) answer sheet and a booklet containing fifty questions. A set of instructions was presented on page one. The student was asked to use an HB pencil to complete the answer sheet; this was necessary for the "marking machine" to recognise the selected answer. In this instance, a calculator was not allowed. It was also stated that the results of the test would not be used for assessment purposes. They would be analysed and a computer printout would be given to each student indicating either satisfactory performance or areas where extra work was advisable.

Upon completion of the test, the staff member attending collected the booklets and answer sheets and returned them to the Maths Support Centre. The centre carried out the processing, and the results were given back at the end of induction week.

The Results

As part of the induction program, students have a half-hour visit scheduled to the support centre. During this time, they are informed of the help that is available, shown the various handouts and how to access the centre website. They are also given back their own diagnosis from the test. The printouts they receive list seven topics and their performance within each.

It is hoped that receiving the results in this manner will help the students to appreciate that the diagnostic test is part of a package, which includes ongoing student support. Students can return to the Maths Support Centre for help from staff or by using the materials available. Special revision classes are also scheduled.

The Barriers

Around ten percent of the OMR sheets cannot be automatically processed. The problem is invariably because the students do not read the instructions. The most common mistake is not properly rubbing out a marked answer when the student changes their selection. In addition, some start doing the test in pen and not in pencil. In this instance, the technician has to copy the results of the test, i.e. make a duplicate with a pencil.

The Enablers

- The test has been running for 12 years. Today, the procedures require limited administrative co-ordination.
- The ongoing collaboration and liaison with the host disciplines has in turn created more credibility for the mathematics department.

How Can Other Academics Reproduce This?

The diagnostic procedure is based not only on the test, but the follow-up support via the maths centre and the links to the host disciplines. Interested institutions need to be aware that setting up this structure is a gradual process

The diagnostic testing began when the Maths Support Centre was opened, with the initial focus being on engineering students. During the previous two years the mathematics department had noted that failure rates were high on certain modules. As a result, they started to identify courses where students were at risk. Diagnostic testing was initially carried out only with students on these courses. However, as a larger number of courses have taken students from a wide range of backgrounds, and as A-Levels have changed, the number of courses using the diagnostic test has increased to the point where virtually all courses with a compulsory mathematics component are involved.

The Maths Support Centre was established with funding from BP. This funding allowed the Centre to employ a full-time manager for three years. The manager co-ordinated and liaised with the various departments. This role was crucial in setting up the diagnostic test across the disciplines and the system as it is today.

Two years ago the university agreed to fund the centre, and this funding was used to employ someone to co-ordinate the test at the beginning of each academic year. This role is important in co-ordinating the test and maintaining the relationship between all participating departments.

References

University Mathematics Support Centres: Help for Struggling Students, in *Applications of Mathematics in Engineering and Economics*, pp 686 – 692, Eds: Ivanchev, D. and Todorov, M. D. Lawson, D. A. and Reed, J. (2002), (ISBN 854-580-115-8), Heron.

Maths Support Centre web-site
http://www.mis.coventry.ac.uk/maths_centre/

For further information please contact Duncan Lawson at
d.lawson@coventry.ac.uk

Paper-based Test

Manchester Metropolitan University

Interview with Norman Ellis and John Dalton ▪ Department of Computing and Mathematics

Abstract

Two weeks are spent doing revision prior to three diagnostic tests. These are designed to assess students' strengths and weaknesses after they have spent some time working in a mathematical context. The tests are all paper-based multi-choice questions (MCQs). They are hand-marked, but owing to the small number of students there is little time delay between assessment and distribution of the results.

The Execution

The three paper-based diagnostic tests are multi-choice, length 45/50/45 minutes. Two are from the same course, but split due to time constraints. They take place in three different rooms. The short nature of the first test means it can be marked and returned to students as they leave their last test. Most students probably don't need a total of 90 minutes for the first and last tests.

The Results

Years	2000	2001	2002
Test 1	59.9	57.2	53.1
Test 2	–	–	62.0
Test 3	78.5	78.5	67.5

Table 1: Average Test Results in % (2000-2002)

The results in Table 1 support the impression that standards have declined in certain areas, with the last result possibly pointing to Curriculum 2000 as a source of concern. Deficiencies are not consistently related to student background. Weak students are directed to further backup material, relevant to their deficiencies. They are also encouraged to sit at the front of lectures (not quite so intimidating where the classes are relatively small) and attend weekly, rather than fortnightly, tutorials. Some staff provide a drop-in centre.

The Barriers

The lack of hard/software resources means a paper-based test is the only route for this kind of assessment. The problem of long assessments is overcome by the forced breaking down of a test into smaller less intimidating chunks.

The Enablers

Providing directed study before arrival, followed by some initial teaching prior to testing, can make it clear what is required and expected, as well as enabling students to give a better account of their capabilities.

How Can Other Academics Reproduce This?

By providing more specific directed study prior to arrival students may get up to the pace required more quickly. Early addressing of known areas where problems are common, prior to testing, can build confidence and a sense of momentum in learning.

Quality Assurance

Manchester Metropolitan University looked to the QAA benchmark for Mathematics, Statistics and Operational Research for its newly designed curricula starting September 2003.

Other Recommendations

Taking time to prepare students for some initial assessment prevents poor results due to 'the long summer break' effect. It means that a truer picture of students' strengths and weaknesses emerge, allowing more appropriately focused remediation.

Looking at the QAA benchmark for Mathematics, Statistics and Operational Research should lead to greater confidence in standards achieved.

Paper-based Test

Queen Mary, University of London

Interview with Franco Vivaldi ▪ School of Mathematical Sciences

Abstract

All students are assessed using a paper-based written test of multi-choice questions (MCQs). The test has 15 questions of which the students must pass with 12 correct. Two hours were allowed. All of the questions were on routine arithmetic and algebra with emphasis on manipulative drill and practice, e.g. decomposition into powers of primes, long division, fractions, BODMAS, surds, elementary function definition, and inequalities. The test is quite demanding and was introduced last year 2001. It is repeated for those who fail six times during the course of the year in a programme called 'Essential Mathematics'. Passing it is a mandatory requirement to proceed into the second year.

The Execution

'Essential Mathematics' is an invigilated two-hour long paper-based multiple-choice test in arithmetic and algebra delivered to mathematics students at QMUL. The environment is that of a traditional invigilated written examination. On the first taking the test is in essence a diagnostic test with repeated tries taking place in a similar environment. Support is given prior to each attempt.

The Results

The test can be repeated up to six times in the first year and must be passed before proceeding to Year 2. The proportion of students that achieved the pass mark in October 2001 was only 4.4%, eventually rising in similar proportions of the whole cohort until the September attempt with 89.6% passes. The mean number of attempts needed by any student to pass this test in 2001/2 was 5 (out of 7) and not surprisingly the response in attending support lectures of students who passed in an earlier attempt was much stronger than from those who passed late or failed. For those who repeatedly fail badly, some of the later training sessions are mandatory, and they must drop a unit (worth 15 credits) from the remainder of the first year programme if they fail the fourth attempt in January.

The Barriers

QMUL take 100 home and 20 overseas students onto the mathematics programme and accept A-Levels at BCC, with the B grade in maths. Most do a 3-year BSc in Maths with about 10 progressing to a 4-year MSc. Because of the decline in classical drill and practice, Essential Mathematics was introduced in the hope that a very systematic reinforcement, to the point of penalty, would improve standards. In some senses the requirement to pass Essential Mathematics is a barrier to students, as they cannot proceed to Year 2 without it, even if other mathematics exams are passed. QMUL has yet to evaluate results and these will not be known till the middle of 2004 at the earliest. So far there has been no adverse affect on recruitment, and applications went up in 2002/3.

The Enablers

Students are required to participate in taking Essential Mathematics. Staff at QMUL believe that the systematic reinforcement it provides is already having an effect on student persistence and confidence but it is too early to say whether or not it will ultimately prove successful.

How Can Other Academics Reproduce This?

Simply by doing likewise, though many institutions may baulk at the prospect of reinforcing drill and skill by a mandatory virtual mastery test. If there is to be such a mastery test, for students of mathematics or even for service mathematics, institutions may wish that it were more broadly based than the test of basic arithmetic and algebra at QMUL.

Quality Assurance

QMUL will monitor the improvements made by introducing a mastery-type test for first year students. It will take three years for a student cohort to complete the degree and only then can results be measured and compared. If successful in substantially improving drill and practice other institutions may wish to follow suit.

Other Recommendations

'Essential Mathematics' at QMUL is a radical departure from other forms of diagnostic testing. Should other institutions wish to consider it, points to consider would be:

- Would you be prepared to make progression into second year contingent upon skill mastery
- Would a mastery test deter students from applying for courses
- Should the mastery test be broader across drill and practice than at QMUL and easier
- Can the institution take the 'risk' with a mastery test whilst awaiting a possible improvement in results over 3/4 years for example
- If the QMUL scheme works will institutions be prepared to adopt a similar scheme based on the QMUL success.

Paper-based Test

University of Strathclyde

Interview with Alison Ramage ■ Department of Mathematics

Abstract

The mathematics department at the University of Strathclyde introduced in 2001 a paper-based diagnostic test to test the elementary mathematics skills of their first year mathematics students.

The Execution

The diagnostic test (at Strathclyde University known as 11.612 Mathematics 1A: Revision Test) was developed last year (2001) by Alison Ramage. The test is paper-based, and taken by the students in class over the course of one hour. Students are required to stay until the end of the hour, but can spend the time after completing the test by thinking about a mathematical 'teaser problem' set by the diagnostic test administrator. The test informs students as well as their tutors of students' mathematical knowledge at the point of entering the university degree course.

The test covers fractions, quadratic equations, powers, trigonometric equations, simplification of equations, about 20 items in total. The emphasis is on testing for basic mistakes that students typically make over and over again. Students are required to enter the correct answer in a box adjacent to the question, and at the end of the hour hand in the entire Revision Test sheet.

There is no overall fitness level recorded for students. Students are not discouraged from doing the degree, for instance based on a poor test outcome. However, individual advice is given, and problems are discussed with the student. In particular, tutors get the diagnostic test results, and can thus identify students that will struggle with the course material. Tutors can then encourage those students to attend clinics and seek extra help.

Follow-up procedures includes office hours, mathematics clinics during lunchtime, as well as TRANSMATH on the web. Students are required to hand in work at lectures. The marks thus gained are not used to grade students, but simply as evidence of their skill.

Students may apply for exemption from certain courses. The decision whether exemption is granted is based on their Advanced Higher achievements.

Prior to arrival students are sent a copy of 'the red book', which gives them sample problems and exercises of the level they are supposed to have achieved. This has the advantage that it allows students to prepare for the test. However, students may also be frightened off by it.

The Results

As the test has only been used twice, there is no data available from it as to how students' mathematical knowledge has changed over time. However, the personal experience of the test administrator suggests that there is probably not much difference over the last ten years. Students' mathematical knowledge over this period is poor compared to what is required at university entry level. However, today's students are probably better at presentations.

Mature students are generally doing better in the degree course, because they made a more deliberate choice to come to university. Female students are usually more diligent.

The Barriers

As the test is only administered for the second time this year, there is not much departmental support for the diagnostic testing procedures. As such, the executing of the test relies on the effort of a dedicated individual. There is not enough money available for processing the test. Postgraduates are not available to help, as they are already busy with a lot of other marking.

The Enablers

As the test happens in a relatively simple set-up (a more or less fixed paper-based test), it can be marked by the administrator. The test results are then looked at by students' tutors, rather than evaluated centrally.

How Can Other Academics Reproduce This?

The test is freely available, and straightforward to administer. Please contact the institution for further information.

Paper-based Test

University of Sussex

Interview with Dudley Ward ▪ School of Mathematical Sciences

Abstract

First year students in mathematics have been tested at the University of Sussex over the past 25 years using a paper-based diagnostic test. The test has hardly changed during that time. The test and remedial measures are co-ordinated by a senior member of staff, but administered by two postgraduates.

The Execution

The diagnostic test is a paper-based multiple choice questionnaire. It was developed at Sussex University in the 1970s and has been practically unchanged since then.

The diagnostic test is taken by students in a lecture theatre over the course of one hour. The students are not required to stay for the full hour and can leave when they wish to. The test is administered by two postgraduates, who are very likely to have met the students before during introductory events.

Students enter answers on a separate answer sheet, which is marked manually by the two postgraduates. The marks are collated, and passed onto Dr Ward, the sub dean of the school of mathematics, who co-ordinates the diagnostic testing and follow-up measures. The test results are used by staff to obtain information about students' knowledge. The test is also intended to give students a better understanding of their skills and informally to gather data for statistical purposes. Although the results of the diagnostic tests are recorded, no overall 'academic fitness level' is produced.

The aforementioned postgraduates also run Mathematical Skills workshops (during the first term only). In these workshops all students work through the Algebra Refresher from the LTSN Maths, Stats & OR Network and the department's own 32 page Mathematics Skills exercises. The exercises done by individual students are allocated individually by the postgraduates. Through these exercises individual student weaknesses (as identified through the diagnostic test and personal contact) are addressed. In the second and third term of the first year, the workshop is replaced by "office hours", during which the postgraduates can be consulted.

If students do not attend workshops, claiming that they do not need to, the results of the test can be used to convince them otherwise. If a student genuinely does not need the workshop he or she is free to work on other problems during the workshop (e.g. on exercises associated with a lecture course).

The Results

Students' skills have gradually declined over the years. As the test has been used since the 1970s (with some small changes during the 1980s due to A-Level curriculum changes), some statistical data is available to indicate this. A two page memorandum was circulated inside the department in 1998. This memorandum indicated that the mean of correct responses (out of 30 questions) fell from 25 to 18.5 between the mid-1980s and the mid-1990s.

Qualitatively students are less fluent at performing mathematics, e.g. integration. However, they are better at note taking, better at project work, have more ability to work on their own, and have better general study skills.

There are no apparent differences in test performance depending on background. However, female students seem to perform better, although there is no data to back this up.

The Barriers

The department currently has to obtain money from various sources on a year by year basis to pay the two postgraduates involved in the diagnostic testing and Maths Skills workshops. Time needs to be scheduled in the students' timetable for the Maths Skills workshops.

The Enablers

In previous years, the Mathematical Skills workshops were allocated to students who needed them. This led to poor attendance. This year all students will go to the Mathematical Skills workshops. Students that have worked through the basic material satisfactorily may use the time to engage and get help with exercises from other classes.

Tutorials (where a teacher works through problems on the board) have been phased out in favour of workshops, where students work through problems on their own under the guidance of a teacher. This also encourages students to help each other. To encourage student co-operation further, provisions have been made in social areas within the department to allow students to work together there.

As the same two postgraduates help with the entire diagnostic testing and remedial programme, students can establish a personal relationship with them. Moreover, the postgraduates are not lecturers or permanent members of staff, but students themselves, which may help undergraduates relate to them.

How Can Other Academics Reproduce This?

The test is freely available. A certain amount of money is needed to pay the people administering the test and remedial measures.

Quality Assurance

Although there are no formal quality assurance measures, the long existence of the test, going back about 25 years, means that it has been tested for a long time. The person responsible for the testing, Dr Ward, has extensive first hand experience of teaching mathematics at school, and is thus able to look at the requirements of first year university mathematics from different perspectives, which is an important element in assessing and improving students' mathematical skills.

Paper-based Test

UMIST

Interview with Colin Steele ▪ Department of Mathematics

Abstract

All students are assessed using a paper-based written test on their first day in the department. The students are allowed to use any non-graphical calculator to help answer 48 questions of the type and standard that they should be familiar with from A-Level. The questions range across simple arithmetic and algebra through logs to differentiation and integration, finishing with some questions on vectors. Final solutions are filled in on an answer grid. The temporary streaming of the students is based on the results.

The Execution

This 80 minute invigilated test consists of 12 sections of four questions each. The test was conducted across five rooms simultaneously on the students' first day in the department. A calculator of a specific type was provided for the students, as was a formula sheet. Answers only were hand marked by the administrator, with a turn around of five days. Test results allowed temporary streaming for the first five weeks of term.

The Results

The test does not count towards the students' final assessment, but does have consequences. For the first five weeks the students are split into two groups; those who performed satisfactorily are provided with enrichment material, the rest do a basic maths revision course. On top of this revision students are encouraged to tackle areas that are indicated to be a problem by the diagnostic test (see [1]).

Following the 5-week revision period a second test is taken to assess progress. For this test a more sophisticated marking scheme will be used. About 30% of students are from overseas and these certainly appear to be better prepared for starting a degree in mathematics.

The Barriers

Clearly the staff time involved is high and the turn-around time causes a delay in feedback. Some students feel unhappy with a test on the first day.

The Enablers

The streaming helps address identified areas of common problems. For the revision course students are taught in small groups, which discourages anonymous absenteeism. Further an attendance record is kept and this can impact on their final course mark.

Reference

[1] *Student Support Based on the Three Stream System at UMIST,* Maths Support for Students, LTSN Maths Team Project, 2003.

How Can Other Academics Reproduce This?

Resources and funding are required to allow the temporary splitting of the year cohort. This requires goodwill of colleagues and curriculum adjustment to compensate for the time the cohort is split.

Quality Assurance

The questions are based on A-Level standard questions. This means performance on the test should really reflect the student's level of competence.

Other Recommendations

The introduction of a new scheme that follows up and addresses lack of knowledge in students by using time at the start of the course should be monitored to verify its impact over the longer term on measures such as student drop out rate.

Section A

A1. Simplify $(a + 3b) + (b - 2c) - (a - b - c)$

A2. Solve the equation $5x + 11 = 36$

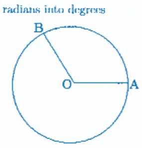
A3. Solve the simultaneous equations

$$\begin{aligned} 3x - y &= -6 \\ 4x + 2y &= 2 \end{aligned}$$

A4. Make x the subject of the formula $y = \frac{7}{x+2} - 1$

Section B

B5. Convert $\pi/5$ radians into degrees



B6. In the circle above, if angle AOB is 2 radians and the length of OA is 3 units, what is the area of the minor sector AOB.

B7. If $\sin\theta = \frac{1}{2}$ and $\frac{5\pi}{2} < \theta < 4\pi$, what is the value of θ ?

B8. Simplify $\sin\left(\frac{3\pi}{2} + \theta\right)$

Example of diagnostic test

Paper-based Test

University of York

Interview with Tony Sudbery ▪ Department of Mathematics

Abstract

Since 1977 a paper-based diagnostic test has been presented to first year mathematics students at the University of York. Based on an interview with the administering lecturer and a student questionnaire this case study examines the procedure, results and student responses to the diagnostic testing process.

The Execution

On 10 October 2002 in the mathematics department, 131 first year students sat a "Mathematics Pre-Knowledge Test". The paper-based test consisted of 39 multi-choice questions that covered a wide range of topics.

Each question had a selection of four possible solutions with a fifth "don't know" option being available. No time restriction allowed the students to work through the questions at their own pace. Calculators were not allowed.

The mathematics department at the University of York teaches students whose degrees are principally mathematics. The diagnostic test has been running since 1977, and is not used by other departments. The test is used to assess the students' knowledge and to identify any remedial actions that may be needed.

The Results

Between 1995 and 1996 there was a marked decline in the average score from 21.2 to 16.5, following which extra questions were added in 1997. The average score has varied little since the new version was introduced (See Table 1).

For the year 2002, the mean score (out of 39 questions) was 21.7, rather lower than last year's mean of 22.9. The median was 21.

14 students scored 30 or more with a maximum of 36 (achieved by two students). Four students scored below 13, with a minimum of 9.

The Barriers

For both the academics and the students there were no obvious problems in the coordination of the test.

The Enablers

The multiple-choice test was marked easily and quickly, ensuring rapid feedback to the students. The results provided a good source of mathematical discussion for the first 2 - 3 weeks of tutorials. In addition, it provided a chance for the tutors to assess overall levels and to consider teaching and support methods to improve mathematical skills.

In relation to the testing environment and the timetabling the responses from the students were positive. They also saw the test as a chance to determine their level of attainment.

How Can Other Academics Reproduce This?

- In this case the maths department produced the multi-choice test.
- In designing such a test, it is important to decide how many questions are needed and which areas will be covered (e.g. trigonometry, calculus, and algebra).
- The "don't know" option reduces the possibility of the student guessing and helps the lecturer determine a topic not learnt or forgotten.
- The multiple-choice format provides easy student use and an ease of marking for the lecturer. However this would change if the student numbers were to increase.
- As the test can be completed fairly quickly there is rapid feedback to the students. This enables follow-up support in the tutorial sessions.
- The use or non-use of the calculator is the choice of the institution.

Quality Assurance

Before 2001, the Mathematics Department repeated the Mathematical Pre-Knowledge test in December (week 9). Just as the first test it was not taken under examination conditions and the average results from 1997 to 2000 indicated that almost all students increased their score. The re-test was however discontinued in 2002.

Year	Oct 1997	Oct 1998	Oct 1999	Oct 2000	Oct 2001	Oct 2002
Number of Scripts	117	103	147	133	127	131
Average Score	22.5	23.4	23.4	22.2	22.9	21.7

Table 1: Mathematics Pre-Knowledge Test – Average Score (out of thirty-nine points) from 1997 to 2002

Computer-based Test

Anglia Polytechnic University

Interview with Neville Dean ▪ School of Applied Sciences

Abstract

The Department of Mathematics, Physics and Electronics (School of Applied Sciences Anglia Polytechnic University, Cambridge) uses DIAGNOSYS to administer a computer-based diagnostic test, testing the mathematical knowledge of primarily foundation year students.

The Execution

The diagnostic test is administered primarily to 70-80 students entering the foundation year, as well as to 5-10 students entering a maths honours degree (a few of which may have come from last year's foundation year). About 40% of the foundation year students come to the university through clearing. The foundation year is a preparatory year for students of science or technology related subjects.

The current diagnostic test used is DIAGNOSYS (Version 3). Different versions of DIAGNOSYS have been used for 6-7 years now. The diagnostic test happens in a very relaxed atmosphere, where students come in at a time of their own choice and take the test in their own time.

The diagnostic test gives students some immediate feedback on their current mathematical strengths and weaknesses. Sometimes students think that their maths is good, and that they do not need to take maths modules. Doing the test, they discover what their abilities really are. By doing the test, the students also feel 'looked after': They feel that both they and their tutors know what their abilities are.

The diagnostic test also gives valuable information to the lecturer who delivers Foundation Maths and helps to determine the level at which to pitch various topics.

The Results

Over the years the mathematical abilities of students entering mathematics honours degrees has dropped. The abilities of students entering the foundation course has not changed, but perhaps even improved slightly.

The performance in the diagnostic test has steadily increased over the years. However, this is not thought to be due to increased mathematical abilities. In the past it was felt that lack of confidence and ability in using computers may have resulted in some students achieving lower scores in the diagnostic test than they should have done. Students now seem to be more confident in using computers, and are generally happier to do a computerised test. Also this year there were more native English speakers entering, which reduced any problems of students understanding what the test questions mean.

On the whole foreign students have better mathematical abilities than home students (the example given was that Irish students do well, with the explanation that this is due to them taking mathematics at school till the age of 18).

Students are typically found to lack in knowledge about powers, scientific notation, rounding to significant figures, and graphs (i.e. "mathematics skills for scientific work").

The department used to have maths surgeries/drop-in centre, and of course offers "office hours" for students to see lecturers.

The department's experience was that the moderately able turn up, but the weak students do not. The department decided to be more proactive in involving weaker students. Current strategy is to assign students to tutor groups (8-10 students per group meeting once a week). Their drop-out rate has improved throughout the last few years, probably due to the tutor groups. Students are reluctant to seek help electronically.

The role of the diagnostic test in this process is not deemed to be crucial. However, it speeds up getting to know students, and identifies students at risk.

There is no direct link between the test and remedial measures. The test informs the tutors of the tutor groups, which then discuss remedial measures with the students.

The Barriers

As the diagnostic test is computer-based, a sufficient number of computers needs to be available. As students come to take the test in their own time, the number of computers needed is small compared to the number of students.

There is some dissatisfaction with the way questions are posed in the computerised test. At times it is not clear to the student whether a numerical or analytical answer is required. The time-out on the duration of the test is not perceived as useful.

There is some dissatisfaction with technical issues surrounding the administering of the test. It was not straightforward for staff to run the test over the network, or to customise the test (changing or adding questions). Generally those involved in administering the test feel that too much of their time is spent on technical issues, rather than actually administering the test and using the test as a tool. The test is perceived as not being administrator friendly.

The Enablers

The introduction of tutor groups, where a tutor is in closer contact with a number of students, and can monitor their progress continually, is seen as beneficial for the students' learning.

How Can Other Academics Reproduce This?

Provided computer resources are available to run DIAGNOSYS this particular model can be implemented at other institutions.

Other Recommendations

The department is currently thinking about choosing a new diagnostic test. The current test suits the department for engineering type degrees (e.g. electronic engineers), but not for foundation year students or mathematics honours students.

Computer-based Test

University of Bristol

Interview with Mike Barry ▪ Department of Engineering Mathematics

Abstract

All students are tested via two computer-based tests each consisting of 10 multi-choice questions (MCQs). These tests are set from a large bank of questions using the 'TAL' (Teach And Learn) computer system developed at the University of Bristol. The topics covered include arithmetic, algebra, geometry, functions, calculus, and probability. A 'leave unanswered' option is provided and negative marking used to discourage guessing. The tests are accessed through a Web interface, so in principle could be accessed from anywhere. It has been run with large-scale simultaneous access and, although a little slow, is relatively robust.

The Execution

The tests were run for all Engineering Students. They took place in two large computer rooms enabling about 100 students to simultaneously access the tests through a web-browser. Questions in the TAL system have time assigned to them so that in a fully (stratified) random setup students may have (slightly) different length tests. If a student is unsure of an answer they may pass over the question and later return to it. Feedback may be provided for incorrect answers, though of course no opportunity to change the answer exists. This year a new, easier test has been introduced, since students were finding the previous versions too hard. The tests remain available for some time if a student wishes to return to a test following a period of revision.

The Results

The fact that the tests have had to be made easier indicates that the skill level of students has declined. Specific areas of concern are logarithms, probability and trigonometry. There has also been a marked decline in the confidence of students. Students are encouraged to take note of questions they have had difficulties with and to seek out study materials in these areas. Once revision has taken place they are encouraged to retake tests. Walk-in sessions are provided for students to seek academic help, as are support classes to address common problems.

The Barriers

The principal problems associated with the TAL system are the unanticipated lack of familiarity some students have with computers, and secondly the speed of the system. This latter problem can be addressed by having a larger, dedicated server for the TAL package.

The Enablers

The fact that TAL tests can be accessed via the web is a major plus. It means that students can access tests from essentially anywhere and that a wider academic community can in principle participate in, and contribute to, the process of teaching and assessing students' knowledge and skills base. The use of a bank of questions and randomisation allows lecturers to have confidence in an automated assessment system giving fair results for an individual without suffering from the fears of widespread plagiarism.

How Can Other Academics Reproduce This?

The administrators of the TAL system are happy to have wider collaboration and participation in the scheme. By contributing a few questions academics can buy into a share of this much larger resource.

Quality Assurance

The TAL system has been in use for a number of years and has been compared to more traditional methods on assessment and diagnosis. Obviously anyone using it would need to go through some sort of benchmarking process against the ability level of their own students.

Other Recommendations

Participating in web-based systems allows for economies of scale and these ideas should be investigated further.

Computer-based Test

Brunel University

Interview with Martin Greenhow ■ Department of Mathematics

Abstract

Brunel is well advanced in promoting good practice in the use of Computer Aided Assessment (CAA). The diagnostic tests are of CAA type, delivered on-screen with full animation at the testing level required (post-GCSE or post A-Level). 200 students are involved on programmes ranging from financial computing to mathematics.

The Execution

The diagnostic tests are of Compuer Aided Assessment (CAA) type delivered on-screen with full animation at the testing level required (post-GCSE or post-A-Level). 200 students are involved on programmes ranging from financial computing to mathematics.

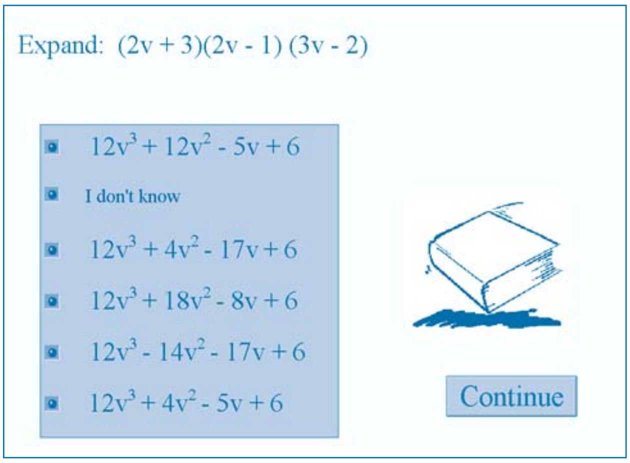
The Results

Brunel has Level Zero and Level One start levels and the capacity to assess/re-assess which level is more suitable for an individual student. Level Zero is largely consolidatory but at Level One students are taught study skills, e.g. preparing a weekly time-plan, and there is (for mathematics) some re-teaching of A-Level in a more axiomatic manner. Formative assessments are used to follow up the diagnostic tests at Level Zero, with Mathletics and paper tests at Level One.

Certainly deficiencies in students' knowledge have arisen in recent years, so diagnostic test results with student profiles go to the individual tutors with collective class profiles going to the Level One co-ordinator.

The Barriers

All surveys appear to indicate that lack of student knowledge at the outset is a barrier to the easy progression that might have been followed in earlier years. Budgets may prevent a level of support that some students might need.



Example of Mathletics question

The Enablers

The budgetary and educational barriers do not influence the smooth running of the diagnostic tests, which operate most efficiently. Every effort, via e/mailing, etc, is made to approach the individual student with his/her learning needs. Although there is no 'walk-in' centre, ad hoc arrangements are made for 1-1 fixed time slots prior to examinations and there are Level One bridging or catch up classes in the first semester only. There are links for budgetary support to the newly funded FDTL4 Physics Project at Reading University, acting in co-operation with the LTSN Maths, Stats & OR Network, to continue with the CAA development started with Mathletics.

How Can Other Academics Reproduce This?

Brunel has been most active in promoting Mathletics (see p8) and has made a CD-ROM freely available. At least 10 other institutions have adopted some of the testing material. A new Web-based version is planned for 2003. With 5000+ questions now available the way is now being prepared for the next generation of questions/tests, which will be based upon Question Mark Perception rather than Question Mark Designer. This will allow generics to be input, e.g. MCQs to solve quadratic equations with random inputs for the coefficients (doubtless within specified margins and real/integer type).

Quality Assurance

Brunel is well advanced in promoting good practice in the use of CAA. It was interesting to see the diagnostic test used in action. Students came in and departed, up to 70 at a time, with minimal supervision. This shows tried and tested robustness that other institutions might be wise to emulate.

Computer-based Test

Keele University

Interview with Doug Quinney ▪ Department of Mathematics

Abstract

All students are assessed via 20 computer-based multi-choice questions (MCQs). These questions are selected at random from a large question bank, developed jointly by Nottingham and Keele Universities. The main objective is to provide a profile of each student's mathematical abilities. Each question tests a number of different skills simultaneously and hence contributes to an assessment of the different aspects of this profile. The profile becomes a diagnostic report, which then directs each student to a series of specific modules in 'Mathwise' that will reinforce their knowledge and correct any problems.

The Execution

Following the provision of revision material from the LTSN Maths, Stats & OR Network prior to arrival, students are given a computer-based test consisting of 20 MCQs in 40 minutes. The test for each student is a stratified random sample of questions from a large bank of questions. Students are allowed to skip and return to questions they are finding difficult. The tests take place in a computer room with 20 or so terminals, over the course of a week. The material covered is essentially that which they should be familiar with from A-Level. The output from the test is immediate feedback of a profile of the student's skills. This is then converted by the computer package into a list of 'Mathwise' modules that the student is recommended to study in order to address any important gaps there appear to be in their skills profile. Results are also followed up through bi-weekly tutorials with a departmental tutor.

The Results

There is some evidence of a slight drift down in skills level over the last 5 years. There are also quite interesting variations in the average student profile from year to year. Differentiation for example has a bi-annual oscillation. For more details see **http://www.keele.ac.uk/depts/ma/diagnostic/keele/keele.html** Discussions that the department has had with the students suggest a much stronger decline in the mathematical *confidence* of students.

The Barriers

Not all students are perhaps as familiar with using computers as might have been expected.

The Enablers

The curriculum has been modified to take a week out and spend it on a differentiation 'blitz'. This has proved quite popular and productive, and is now being augmented by an integration 'blitz'. The use of the testing package and its directing of 'Mathwise' study are useful in addressing some of the diverse needs of individual students.

How Can Other Academics Reproduce This?

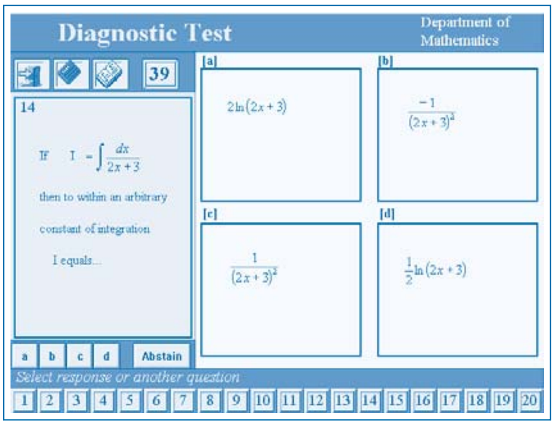
Simply by doing likewise. The testing package is freely available and could be used by other institutions. There is some cost associated with the 'Mathwise' material. The real strength of this approach is that once possible weaknesses are identified, a suitable course of action is recommended. All of this can be done without significant academic time input.

Quality Assurance

The computer-based test has been compared to similar paper-based tests and found to produce comparable results. To make it work it is necessary to provide the time, resources and encouragement to students to make the most of the profile and guidance provided by the diagnostic test.

Other Recommendations

This case study provides an ideal model of what could be achieved. Automated assessment of students' strengths/ weaknesses, immediate feedback, and a directed course of remediation.



Example of question

Computer-based Test

University of Newcastle upon Tyne

Interview with John Appleby ▪ School of Mechanical and Systems Engineering

Abstract

DIAGNOSYS has been used by the Department of Engineering Mathematics, now the School of Mechanical and Systems Engineering, since 1993. By 1996 there were five departments involved in using the software. Based on an interview with the administering lecturer and a student questionnaire this case study examines the procedure, results and student responses to the diagnostic testing process.

The Execution

DIAGNOSYS was first used by the Department of Engineering Mathematics at the University of Newcastle upon Tyne in October 1993. Developed under the Teaching and Learning Technology Programme (TLTP), the computer package is an intelligent knowledge-based system for testing background skills in basic mathematics or other technical subjects.

By 1996 five departments were involved in using the software: Chemical and Process Engineering, Civil Engineering, Electrical and Electronic Engineering, Marine Technology and Mechanical, Materials and Manufacturing Engineering. The testing process included entrants into the Engineering Foundation Course, Stage 1 of Mechanical and Materials degrees and all first year students to the Faculty.

Nowadays it is an essential tool in assessing students' mathematical knowledge. It is used to help individual students identify their level of attainment and to provide support for those with special needs. It is also used in the curriculum design for groups of students and in the assessment of the selection policy.

During the first week of the 02/03 academic year 49 students were observed sitting the DIAGNOSYS test within a scheduled computer session. A common logon enabled the tutor to set up in advance. Each student entered their name, department and the level of mathematics they had previously attained. Based on this information the package decides the level of questions to ask initially.

At the beginning of the test there is an optional tutorial on how to enter different types of answers (number, multiple-choice, algebra) which provides an opportunity for the student to get used to the interface.

What follows depends upon the success rate of the students: those achieving a good success rate can quickly pass from one topic to one more advanced; those less successful are taken on a 'slower' route. The test terminates when there are no questions left to be asked or when a time limit is reached. The student at this point does not have access to the performance details.

Each topic area contains several questions at a given level and one is chosen at random for each test. Coupled with the 'expert-system' approach, which gives each student a different path through the test, each student will be asked a completely different set of questions, which helps prevent cheating.

The Results

The results are stored on the server as individual text files; at the end of the group test, they are downloaded by the tutor and transferred to a disk. The information is printed out and given to each of the students.

The text files sent to the tutor create the following:

- A group profile of all the students tested
- A ranked listing of the students in terms of score
- Tabulated answers actually given to all students (to highlight common misunderstandings)
- Results of all questions and skills for subsequent spreadsheet analysis
- Combined files of individual 'profiles' ready for printing.

The Barriers

There appeared to be no major problem with the co-ordination of the test for either the students or the academic. Any problems with the computers or entering the information for the test were quickly overcome; the academic was available to provide assistance throughout the testing session.

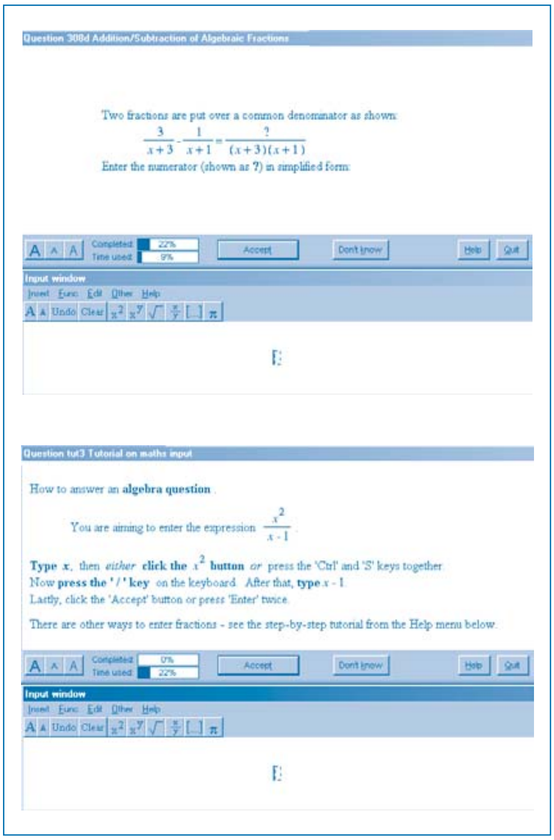
The Enablers

- DIAGNOSYS requires no time for test creation since its database contains hundreds of 'ready to use' questions, but some customisation is needed for initial menus of courses etc.
- Self-testing modes complement the main diagnostic mode, enabling students to address weaknesses and develop skills. They can re-take the test; comments enable them to monitor their own progress and have more than one attempt at the answer.
- For the academic the package is flexible and output can be controlled. The system can be customised and other questions can be designed. Full documentation on how to do this is provided with the software.
- The package incorporates automatic marking facilities, giving instant comments to both the individual student and the lecturer.

How Can Other Academics Reproduce This?

The software is available from the DIAGNOSYS Project, School of Mechanical and Systems Engineering, University of Newcastle, Newcastle upon Tyne, NE1 7RU.
Email: **DIAGNOSYS@ncl.ac.uk**

The demonstration version (time-limited) can be downloaded, trailled and customised before ordering from the website:
www.staff.ncl.ac.uk/john.appleby/diagpage.htm



Example of DIAGNOSYS questions

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