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Diagnostic testing of first year pharmacy students: A tool for targeted student support

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Abstract

Since 1997, incoming students to the School of Pharmacy and Pharmaceutical Sciences at the University of Manchester have been required to sit diagnostic tests in English, Mathematics, Chemistry, Biology and Physics. The tests have several purposes: (a) to help assign students to appropriate foundation courses, (b) to identify any areas of group or individual weakness, and (c) to determine any movement in the A-level syllabuses and standards as they affect Pharmacy students. We now show that the tests can be used to identify students at risk of failure during the MPharm course. Serious risk factors include failure to attend the tests, scores of below 90% by home students in the English test, and scores of below 60% in the Chemistry test. The year-to-year mean scores in the tests are essentially constant, although the mean A-level scores of the intake have risen. The extensive validation of the diagnostic tests by incoming students now additionally allows us to use the tests to inform the admissions process, where students' entry qualifications are otherwise difficult to assess.

Keywords: *Attendance, English support, diagnostic testing, pharmacy students*

Introduction

In 1997, the School of Pharmacy and Pharmaceutical Sciences at the University of Manchester introduced a set of diagnostic tests in Chemistry, Mathematics, Physics, Biology and English, to be taken by first year students during Freshers' week (the week before the start of formal teaching). The main objectives were:

- to identify individuals in need of additional support;
- to identify specific support required by the whole group or a substantial proportion of it; and
- to assess students' levels of preparedness for the course and to monitor any significant changes with time. The aim was to use the same canon of tests over many years (perhaps 20) to monitor changes in the knowledge and skills of the first year intake.

Traditionally, Chemistry is the core science on which the study of Pharmacy depends. It is the only subject in which an A-level or equivalent qualification is required by this School of Pharmacy as a pre-requisite for study. However, it has become increasingly important to monitor students' entry levels in other subjects. A facility with basic Mathematics is clearly required by the practising pharmacist. Concern has been expressed that GCSE and equivalent qualifications do not always ensure that the required skill has been achieved (The Engineering Council, 2000; Haigh, 2002). Biology, in contrast, has become more important in our understanding of drugs and their uses. The growth of understanding of pharmacokinetics and genomics (to give but two examples) must be reflected in the knowledge of the practising pharmacist. The multi-cultural nature of our society and the mobility of the workforce mean that we can no longer take essential communication skills for granted. A study on the 2003 Pharmacy intake (Turner and Barber, unpublished) indicated that English was the second language for 28% of this cohort. Being proficient in languages other than English is potentially very advantageous in the workplace; however, it is an adjunct to, not

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a substitute for, a good level of English. Physics, though (currently) the least important (for Pharmacy) of the subjects tested, underlies much of the Physical Pharmacy studied during the MPharm programme.

The diagnostic tests were intended for evaluation purposes only, and they are not part of the formal examination system. Compared with the entry qualifications, diagnostic test results offer more detailed information on students' knowledge. They test basic abstract knowledge in subjects that have not necessarily been studied at A-level, as well as testing students' basic linguistic skills. At the same time, the main focus of the questions are pharmacy-based. These tests provide an assessment of students' typical initial knowledge, prior knowledge being considered to be the most important factor in learning (Ausubel, 1968). Correlation between diagnostic test results and University mid-course examination results can be used for monitoring the progress either of individuals or of the group.

The diagnostic tests also have the potential to distinguish between weaknesses in individuals and those which affect groups of students. The diagnostic tests deliver a much more detailed profile of a student's prior knowledge than is obtainable from their A-level results, and so shortcomings affecting specific sub-groups of students (e.g. those with English as their second language) can be effectively monitored. This in turn can inform the development of appropriate remedial help and support systems for groups of students (e.g. offering language support for students with problems with English). At the same time, a comparison between diagnostic test results and subsequent test results can highlight any potential decline in individuals' standards of performance, alerting staff to potential problems that may benefit from timely intervention.

Among the drivers for the introduction of these diagnostic tests was the great diversity of entry qualifications among the student intake. In the past nearly all students had traditional A-level qualifications; by 2005, over 10% of the intake had overseas qualifications, or had completed miscellaneous foundation programmes or technician courses, or were graduates in related or unrelated subjects. Many of these students were from groups targeted by the government's Widening Participation initiative.

Diagnostic testing is used extensively in universities worldwide, generally to inform the content of taught courses or to identify students in need of remedial help (Quinney, undated; The Engineering Council, 2000). The literature from pharmacy schools in the UK is concerned with the diagnostic testing of Mathematics deemed necessary as a result of increased access to university and of less-traditional entry qualifications (Batchelor, 2004).

This is the first study of the value of diagnostic testing across the range of pre-requisite skills and knowledge for a Pharmacy degree. The study is long-term and on-going. We now report our experience of diagnostic testing during Freshers' Week over the nine years from the introduction of the four-year MPharm programme in the UK.

Methods

Initial testing protocols

The Chemistry, Biology, Mathematics and Physics tests were written in the School of Pharmacy of the University of Manchester (Barber & Gifford, 1998). Each test was designed to take 30–40 min to complete, and typically contained 50 questions. Each aimed for an average mark of about 70%, so that students would be encouraged, rather than discouraged, by their results. It was important to test material ranging from Key Stage 3 (or even below) through to A-level. The question "Does the student have a basic knowledge of this subject?" was just as important as understanding whether the student had a good grasp of A-level material. The English test is a Chaplen test (Chaplen, 1990), developed within the University of Manchester by the English Language Teaching Unit (now English Language Programmes) for use with overseas students.

The AH4 IQ test (Heim, Watts, & Simmonds, 1975) was used during the period 1997–2001 as a control, and was administered under the guidance of members of the School of Psychology. Both this test and the Chaplen test were piloted on a large group (60 students) during 1996. Despite the fact that these tests are short (10–18 min) and timed, no serious problems associated with the large numbers of candidates were identified. Students are given a Freshers' week timetable before they arrive for the start of the term, and therefore have some notice of the tests. They are told, however, that these are spot tests for diagnostic purposes only. Students are advised to discuss the results with their tutors if they are concerned.

Although the tests were developed with Pharmacy students in mind, they are not subject-specific. Indeed, in the original proposal, transferability of the tests to other departments with little amendment was anticipated (Barber & Gifford, 1998). The tests were adopted by the Department of Chemistry for the first time in 1999. Unlike Pharmacy students who participate in all the tests, Chemistry students sat only Mathematics, Physics, and English papers; students of Chemistry with Medicinal Chemistry also sat the Biology test. Chemistry students were exempt from the Chemistry test, in an attempt to avoid unnecessary anxiety among students who by definition would all be studying the subject.

Modification of the testing protocol over time

The Chemistry and Biology tests were designed in multiple-choice format from the outset. These papers are essentially unchanged since 1997. The Physics paper underwent radical changes in 1998 and 1999, the 1999 version being in multiple-choice format. Initially, two different tests in Mathematics were used: one for students with an A-level in Mathematics, and one for those without. The revised version in 1999, however, was a single paper, including questions at all levels from Key Stage 2 to A-level, and was taken by all first year students. In 2002 a new Mathematics paper was introduced for two reasons: (i) a wider variety of question type was felt to be desirable, and (ii) tests were also being used as part of the admissions process and separate tests were preferable. The standard of the new test was validated against the previous one, i.e. students who attempted both the existing and the new version of the Mathematics test scored similar marks.

In 1999, all the tests were converted into web-based versions, allowing students to obtain their results immediately after completing the tests. The main advantages of computerised tests are:

—savings in time and resources necessary for marking the tests.
—almost immediate identification of students at risk of underperformance, hence providing departments with the opportunity to initiate a plan of action very early in the course.
—avoidance of unnecessary anxiety among students whilst waiting for the outcome of their tests.

In 2004, the Mathematics test was changed to multiple-choice format to make it compatible with a variety of platforms for computer-based assessment. Between 1999 and 2004, text-match style questions were also used.

Results

Logistic problems and their solutions

The Pharmacy intake has risen from 115 in 1997 to a peak of 193 in 2005. Results from the diagnostic tests are required within two days of administration if they are to be used to inform Foundation course choices. Paper-based assessment is therefore impractical.

Computer-based assessment of this number of students brings its own problems, however. In the period 1999–2004, only a single session (2002) was problem-free. A detailed protocol is now in place that provides contingency plans for the reasonably foreseeable problems associated with large-scale computer-based testing. The most important features of this protocol are the use of software that does not require prior University registration (this is unobtainable for a whole cohort on the first day of their course), and the availability of hard copy in the event of a serious computer failure (for example, the virus that afflicted the entire University network in registration week in 2001).

Attendance

Each year a small number of students (11% of the 1997–2005 Pharmacy intakes) fail to complete one or more of the diagnostic tests because of very late arrival at a timetabled session or through missing the session altogether. A log-linear analysis indicated that students who absent themselves in this way and who fail to take advantage of alternative opportunities to complete the tests are on average 2.3 times more likely ($z = 4.35$) to withdraw from the course than other students. This correlation is now taken very seriously by the School of Pharmacy, and such students receive a warning letter from the Work and Attendance Committee. It is too early to determine whether this intervention will prove effective.

General performance in the diagnostic tests

The average performance of each intake in the diagnostic tests, over the course of nine years, is illustrated in Figure 1. The overall performance is more or less static. With respect to Mathematics and Physics, the largest changes in performance coincide with changes made to the papers. The performance of students with a total A-level point score of 24 (the most common score) was also compared over

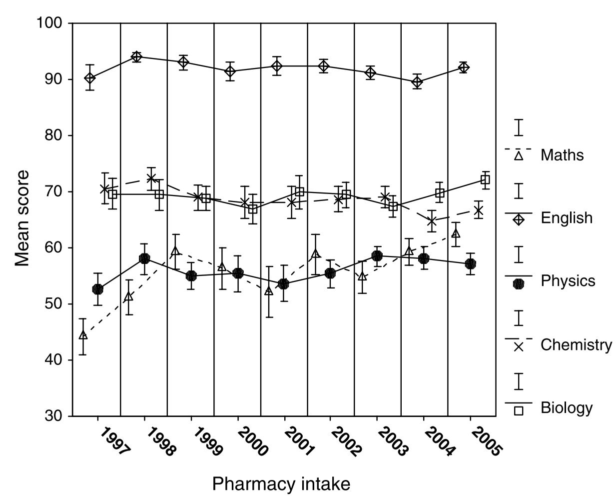

Figure 1. Mean score obtained in each diagnostic test by different intakes (1997–2005). All students are included irrespective of having an A-level or equivalent qualification in a given subject (numbers of students who took the each test are as follows: Chemistry = 1226, Mathematics = 1216, Physics = 1178, Biology = 1214). (For clarity, the plots corresponding to the different tests are slightly displaced in the × dimension, within the bands corresponding to each intake.)

Table I. Average score in the Chemistry test and first year examination of male and female students. Numbers in brackets refer to standard deviations and "n" is the number of students in each category.

Gender	Mean score in Chemistry test	Standard error of mean (Chemistry test)	Percentage of mark in first year	Standard error of mean (first year result)
Male	69.19 (12.11) $n = 340$	0.66	59.11 (11.26) $n = 273$	0.68
Female	66.51 (11.18) $n = 514$	0.49	63.00 (11.18) $n = 416$	0.55

the test period (1997–2006). With the exception of the Mathematics and Physics papers, which underwent radical changes, no significant difference in students' performance was observed.

Gender differences

Although aptitude tests in general tend to favour males (Choppin, Orr, Kurle, Fara, & James, 1973; McCammon, Golden, & Wuensch, 2003) we found no significant differences between the performances of men and women in most of these diagnostic tests when A-level profiles were taken into account. The only exception was the Chemistry test, in which males outperformed females ($t = 3.32$, $p < 0.01$) by about 2% (Table I). Here, all students had an A-level or closely equivalent qualification in Chemistry and the comparison was made over all students. In the first year examination results, however, women outperformed men by 4% ($t = 4.45$, $p < 0.001$). The consistently stronger performance of women than men on this course has been reported previously (Sharif, Barber, Morris, & Gifford, 2003), and is the subject of further investigation, to be reported later.

Correlation of diagnostic test results with first year examination results

Results in the Chemistry, Biology and Mathematics (but not Physics) diagnostic tests correlated positively but weakly with first year examination performance for students with A-level entry qualifications (Table II and Figure 2). However, our particular concern at this point was with students who performed significantly below the mean in the diagnostic tests. The tests were designed for a mean score of approximately 70% and the lowest reasonable score was considered to be 60%.

Table II. Pearson correlation coefficients for correlations between scores in the diagnostic tests and first year examination for students with A-level entry qualifications.

	Pearson correlation coefficient	Number of students
Chemistry	0.2**	669
Mathematics	0.1*	665
Biology	0.2**	665
Physics	0.1	943

*Significance level = 0.05; **Significance level = 0.01.

Table III shows how the Chemistry test in particular can help identify weaker students. Those scoring below 60% in this diagnostic test achieved significantly lower examination results than those scoring above 60%.

Interestingly, the students who score below 60% in the Chemistry diagnostic test seldom fail the Chemistry course examinations. The first year Chemistry modules in Manchester are intensive and include 14 h of tutorials in the first semester. Students deemed at risk are encouraged by the course tutor to make use of the help available. No additional timetabled remedial support has been deemed necessary. This approach has been consistently validated by the performance of first year students in Chemistry examinations. There are very few failures and these few are almost invariably multiple failures.

The first semester of the MPharm course includes foundation modules in Biology, Mathematics, Physics and English. Students with poor scores in the diagnostic tests are directed to attend the appropriate foundation modules. In a few cases, attendance at more than the usual two foundation modules is indicated. These are handled on a case-by-case basis, but there is a clear hierarchy: deficiencies are addressed in the order English, Mathematics, Biology and Physics. Our previous work demonstrated the fundamental importance of English in the study of Pharmacy, and both our own findings and those of a recent study from the University of Aston (Batchelor, 2004) point to the importance of Mathematics. The relatively low priority of Biology is additionally justified by the presence in the second semester of a substantial module in Cell Biology and Biochemistry, for which A-level is not a pre-requisite.

Discussion

We report an ongoing investigation of the value of diagnostic testing of students entering a Pharmacy undergraduate programme. We have chosen to test a wide range of knowledge, because of the wide variety of skills required by Pharmacy students and by practising pharmacists. The pragmatic, readily sustainable model involves multiple-choice, computer-based tests that can easily be transferred from one computer program to another, as need dictates. The commercially-available Brownstone Diploma Campus software (Horizon Wimba Inc., 2006) satisfies most of our

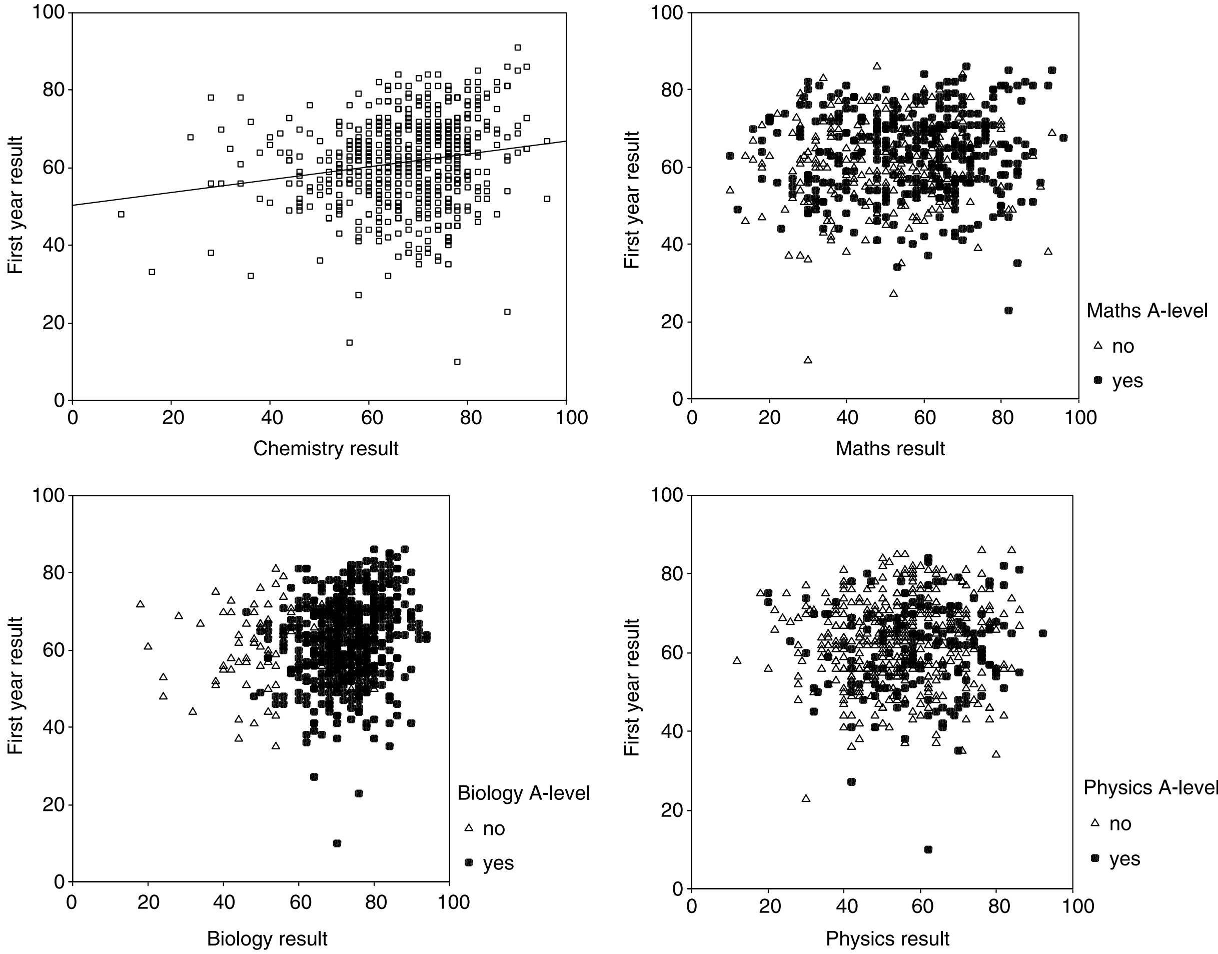

Figure 2. Relationship between the diagnostic test scores and first year marks for students. Only students with A-level entry qualification are included, i.e. those with qualifications other than A-level were excluded.

requirements (especially that prior registration on the University system is not required) although it lacks the facility to terminate and mark tests automatically when the time limit has been reached.

The earliest indicator of potential work and attendance problems is when a student fails to attend one or more tests. Failure to attend the tests is a significant risk factor for failure to complete the course. Although the School's Work and Attendance Committee now intervenes almost immediately this risk factor has been identified, it is not yet clear whether this intervention is effective in raising attendance. Students are informed that attendance at the tests is a requirement, and it is gratifying that in 2005 only one student was absent without prior authorisation.

Table III. Average first year examination mark of pharmacy students with A-level entry qualifications who scored 60 or more in the diagnostic tests, compared with those who scored below 60. Numbers in brackets refer to standard deviations.

Diagnostic test	Percentage of score in the test	First year exam mark	*n*	*t*
Chemistry	Above 60	62.31 (11.43)	544	3.34*
	Below 60	58.58 (10.47)	125	
Mathematics	Above 60	62.94 (11.19)	276	2.60*
	Below 60	60.62 (11.43)	389	
Biology	Above 60	62.02 (11.35)	565	1.93
	Below 60	59.67 (10.58)	100	
Physics	Above 60	62.14 (11.82)	250	1.26
	Below 60	60.67 (11.17)	393	

*Significance level = 0.01; "*n*" is the number of students in each category.

Science test results (Chemistry, Mathematics and Biology) correlate weakly with overall first year examination results. A-level scores discriminate poorly between Pharmacy students in this sample because of its homogeneity—few students have other than A or B grades, whereas the diagnostic tests span a much wider range (22–90% in 2005) and are more sensitive predictors. We consider scores of less than 60%, in any subject for which an A-level or equivalent has been completed, to be a risk factor for examination failure, and interventions which vary from subject to subject are put in place. The most stringent intervention is in Mathematics; all students who score less than 60% are required to pass the Foundation Mathematics course test, regardless of whether they are registered for the Foundation Mathematics module.

We would anticipate (and hope) that the subject-specific interventions in place in the first year course are effectively reducing correlations between diagnostic test and examination marks. The analysis of many years' data shows, however, that a correlation persists between the individual diagnostic tests (especially in Chemistry) and (subject-independent) examination results. This residual correlation is probably a reflection of the different abilities, motivation and circumstances of the students. Nevertheless, it is always helpful to identify the weaker students at the earliest possible stage of the course.

The near-absence of gender differences in the test scores is interesting, and is, of course, reflected in the A-level scores of the incoming students. The first year examination results, however, show women significantly out-performing men, as we have previously reported (Sharif et al., 2003). It may be that A-level grades, however fair and objective, do not alone deliver the optimum MPharm intake, and that on average women perform better (relative to men) on the degree programme than in A-level examinations. The diagnostic tests do not improve on A-level grades in this respect. Preliminary data indicate that it is possible to construct a model, based on A-levels plus either GCSE grades or interview scores, which correlates more closely with performance on the course than A-level grades alone, and this will be the subject of a future report.

The most important finding during this study was a positive correlation between English test results and examination scores for the 1997 intake (Sharif et al., 2003). This was sufficiently striking that significant remedial action (in the form of timetabled English support) was taken immediately; the module Academic Literacy, the successor to this earlier support, remains a part of the first year curriculum and is taken by about 60% of the intake. The correlation between English test scores and final year examinations ceased to be significant in 2002 (the 1998 intake) and Asian and British Asian students now perform similarly to white and Afro–Caribbean students. Additional, more intense, language support is available through the Faculty of Humanities for individuals close to the minimum standard for admission (IELTS 7.0 or equivalent), and is most frequently taken up by students of Chinese ethnic origin.

We have seen no significant changes in the performance of students in the diagnostic tests since 1997, other than the slight improvements in Mathematics scores paralleling changes in the test format. Over the period 1997–2005, A-level results have risen slightly at national level (Baker, 2002; Batchelor, 2004); the A-level scores of the MPharm intake have also risen slightly during the same period.

Since 2001, the diagnostic tests have been used to aid the admissions process, and in particular to identify good "Widening Participation" students. The canon of tests has been validated by hundreds of students, and is a useful admissions tool for students whose suitability for the MPharm. course is otherwise hard to assess. These include students on Access programmes, those on foundation courses, mature students, students with certain overseas qualifications and, most memorably, a student who reported that his degree certificates had been destroyed by the Taliban. Typically, around 50 students are invited to a special interview day each year, and required to sit the diagnostic tests and to achieve standards that indicate that they are not at serious risk of failing the course. A very variable number of students satisfy the standards for admissions; latterly offers of admission have been made to about a quarter of those sitting the tests.

In conclusion, the diagnostic tests have proved to be a valuable tool in a number of respects. We expect to continue to use Mathematics, English and Chemistry tests for diagnostic purposes. The Physics and Biology tests have not proved sensitive predictors of examination failure and cannot therefore be regarded as especially beneficial to students, although they will continue to be used for admissions purposes.

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