Independent Learning in an Introductory Module in Biological Chemistry: Use of Question Mark™ **Software to Provide an Assessment Tool and Tutorial Support**

PAPER

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In designing a new first year module in biological chemistry we aimed to eliminate lectures which we regard as a fairly ineffective way of imparting factual information and replace them with high quality handouts and a recommended text. Students were issued with a programme of structured study and assessment at the start of the module. Two hour tutorials were held weekly on questions/discussion topics previously given to students. This was the only formal (timetabled) contact between staff and students. Students worked their way through the subject material during 12 weeks and were assessed at fortnightly intervals using Question Mark™ software. This not only allowed us to monitor the progress of students but also imposed on them a structured programme of study. The results of the tests were available immediately to students and to staff. In the periods between tests, students had access to the computer laboratories to do practice questions. These questions all had feedback, so that if a student gave an incorrect answer an explanation could be given as to why it was incorrect. We found the QM software to be well suited to introductory chemistry – tests which are challenging and have considerable variety can be constructed. A survey of the students indicated that two thirds of the class thought that this style of learning was better or much better than lectures and none thought it was worse.

Introduction

We were asked to design a new module called 'Introduction to Biological Chemistry' which was to be studied by first year students embarking on Health Science courses.

The design of the module had to take into account not only the subject content and pedagogical approach but also cost effectiveness. For well-documented financial reasons[1] departments are increasingly under pressure to increase the efficiency of teaching. In our case this meant that the module had to be suitable as a foundation for a *range* of life science courses, without compromising the needs of students and the educational objectives of the individual programmes to which it contributes. Ideally, the module would also take account of the reduction of the number of academic staff and the pressure to reduce the use of valuable teaching accommodation.

Trigwell *et al* have studied the various strategies used by lecturers to improve learning by students in first year science courses[2]. At one extreme strategies were based on highly *teacher-focused* activities, where there was little or no interaction with students and where students had little or no responsibility for the teaching-learning situation. Typical of this approach was the provision of notes, perhaps with gaps which had to be completed by students, but where there was little freedom given to students to decide how *they* should take notes. The main intention of this approach was *information transmission*. At the other extreme, strategies involved highly *student-focused* activities, where students were very much more in control of and responsible for their own learning. An example of this approach is provided by White [3,4]. His innovative programme is unlikely to be viable in most UK institutions because of the high load on the teacher and the small enrolment.

Whatever approach is adopted, it is useful to take account of established theories about the way students learn. Some useful reviews dealing with this are available (for example[5,6]). As Boothroyd has pointed out[7], it is easier to acquire knowledge by independent learning than it is to acquire understanding and skills in applying knowledge; this leads to a powerful argument that a tutor's limited time is best spent in helping students with these more difficult aspects of the learning process. Furthermore, in a course where teachers concentrate on the acquisition of knowledge there is a risk of reinforcing the dualistic view of the world used by those in the first stage of intellectual development defined by Perry[8]. An introductory course needs to recognise that many students, being in this position, still expect teachers to be able to provide 'correct' answers to everything. Only when the 'language' of chemistry has been learned and a foundation established are students likely to proceed to the higher orders of reasoning described by Perry. However, at the beginning of most university chemistry courses there is undoubtedly a strong emphasis on the acquisition of factual knowledge and its simple processing.

A further complication for us was that we had to cater for a diverse client group of students with a range of educational backgrounds and wide disparity of chemical/scientific achievement. The traditional lecture approach did not seem to us to be a particularly efficient way of meeting the requirements of such an inhomogeneous body of students. An approach involving self-paced learning which lay somewhere between the two extremes described by Trigwell seemed to be more appropriate. This would also fulfil the requirements of reducing the contact hours for tutors and reducing the demand for teaching accommodation. Furthermore, previous experience with an introductory biochemistry module for physiotherapy students had shown that a structured programme of work based on detailed handouts and informal lecture/tutorial classes for students experiencing difficulty could work successfully[9,10]. The key to its success was regular computer-based testing which gave the students an incentive to keep up to date with their studies.We have developed and refined this approach in a number of ways and produced the module described here which was initially incorporated into a new degree programme in Clinical Science. This programme also included modules in introductory physics, anatomy and physiology in the first year.

Module content and teaching strategy

The aim of the module was to develop within students a knowledge and understanding of the chemical basis of life processes. The syllabus was loosely based on an introductory text on chemistry for the life sciences[11] and progressed from atomic structure and bonding through the topics: chemical reactions and kinetics,solution chemistry,organic compounds, carbohydrates, lipids, amino acids, proteins, enzymes and metabolism. There was no laboratory work. The emphasis throughout was on relating the chemistry to biological functions and to subjects such as physiology, nutrition and microbiology;it was not the intention to establish a foundation for the further study of chemistry and so the syllabus content was necessarily selective and illustrative rather than comprehensive.

The module was designed on the following principles:

- there were no lectures;
- the syllabus would be defined by eight handouts representing a unit of material; handouts would be provided at appropriate intervals throughout the 12 week module;
- the learning experience would be enhanced by stimulating self-assessment questions available on a computer network;
- tutorial support would be provided by a weekly compulsory two-hour class when the whole cohort (about 14 students) would meet to discuss sets of open ended problems which would be distributed seven days beforehand;
- additional structure would be provided to the learning environment by using fortnightly computer-based tests to assess preset goals;
- assessment would be based on the results of the computer-based tests representing coursework (60%) and an end of module examination (40%); (this division is required by course regulations).

Students who enrolled on the module met the tutors at induction, and the operation of the module was discussed. Students were arranged into groups of three as a basis for peer support. They were issued with a week by week timetable of events which showed when particular handout material was available and when self-assessment questions for the material would be loaded on to the computers. The fortnightly tests contained questions similar but not identical to these practice questions. The software allowed the tutor to monitor the progress of each student and could highlight areas of particular difficulty or indeed if they were not maintaining a reasonable study schedule.Records of each student's attempts at both the practice questions and the official tests were available to the tutors, but only the latter were retained for incorporation into the coursework mark. Students could access practice questions in the computing laboratories during sessions which were timetabled for two hours per week but were also available for access at other times. The questions were based mainly on the handout material, testing both acquisition of information and simple processing of this information. The programme provided comprehensive feedback, linked to individual responses of students, as well as individual scores.

During the two-hour weekly tutorial session students worked in their arranged peer groups on the open-ended problem and topic exercises.Examples of these are shown in Figure 1.They were designed to engage the student creatively with the material to provide opportunities for the tutor to explore with the students the wider implications of the subject. This type of interaction fits with Boothroyd's concept of using the tutor for 'higher order' aspects of learning[7]. It also gives an opportunity to discuss what type of response is required in the end of module examination.

The eight-unit handouts together are the equivalent of a small book of approximately 120 pages. Each unit consists of an outline, objectives of the unit, content, keyword list, set of discussion topics and problems, and some include self-assessment problems. The handouts were prepared from tutors' notes and diagrams by two (part-time) post-graduate students.They used the Pagemaker™ DTP package and Corel Draw™ for diagrams to create high quality colour-illustrated material. Reference to the introductory text book[11] was included for those students who needed further information.

The same postgraduate students also created the bank of about 400 computer-based questions (with feedback) using

Figure 1: Examples of problems and topics for discussion used in tutorials

Discussion topics:

1. What is a mole?
2. How are reaction rates measured, and how does the information gathered lead to a proposed mechanism?
3. What are the essential features of carbohydrates that suit them to their various biological functions?

Problems:

1. Identify the functional groups in (1) LSD (2) ATP
2. Draw the disaccharides of glucopyranose that are linked by the following glycosidic bonds:
   α-1,6-
   β-1,3-
   α-1,2-
   α,β-1,1'-
3. Rotation about the C-N bond of peptides is very difficult. From the table of bond lengths, what can you infer about the nature of the C-N bond?

the software package Question Mark Designer™ for Windows (QM).This is a dedicated assessment tool produced by Question Mark Computing[12] and is described in more detail in the next section. The tutors drafted questions, together with feedback, for each unit; the postgraduates transcribed these into QM format, including appropriate diagrams in Corel Draw. Selected questions were then reserved for the fortnightly tests, and the remainder were made available for practice when the students were studying the units. The questions were then set up on the server in a networked computer laboratory.

Other authors have used authoring packages such as Authorware Professional[13] and Toolbook[14] to produce CAL material to support the learning of chemistry.This material met only a small proportion of our needs and we had in any case decided that the availability of printed material gives the students much more flexibility to choose the time and place for their studies. This point is recognised by others who have pointed out that teaching material is not necessarily best delivered by computer (*eg* [15]). Although Authorware and Toolbook can be used to write assessments it takes much longer to master their intricacies compared to QM. Further advantages of the QM software are that it records student performances and an integral part of the software is the statistical analysis of responses. Also the QM company maintains an e-mail users group[16] which allows sharing of experience of assessment between different users.

Feedback and testing with QuestionMark Designer™

A brief review of QM software is given by Dempster[17]. We used windows version 3.10 which was installed on a local network. It is possible to deliver questions over the *Web*, but compared to the networked version there are two main disadvantages: certain types of question are not available and feedback cannot be given directly after a student makes a response to a question[18,19]. The QM software has been a key element in the success of our approach. In much assessment software, question formats are restricted to multiple choice questions (MCQ), which are not only difficult to create if they are to be effective but also are not appropriate for the assessment of all aspects we wished to test. In contrast, QM has a varied and interesting selection of question formats which are more easily applied to different types of problem over a wider range of the syllabus. As with other assessment software, students are given instant feedback on their response. Anyone who is familiar with Windows can quickly assimilate the QM software (both the question setter and the student); there is no need to learn any internal programming language. The editing of questions is easily carried out by tutors.

The types of question available in QM are illustrated in Figure 2. Once familiarity is gained with the different types of format, designing questions is a fairly rapid process. Essentially each type of question is provided as a visually attractive template into which the teacher inserts appropriate text, graphics or multimedia material. For example the *hot spot* question can incorporate multiple 'live' spots in a diagram (*eg* a graph, an equation, a figure, a chemical formula). When the student selects a particular *hot spot*, feedback which is specific to that spot can be given. The *selection* question presents multiple choices of answer (usually a one word answer) to each question asked. For certain types of question *supplementary questions* can be asked allowing the student's answer to be elaborated in greater detail. Feedback normally appears on-screen, superimposed on the question, immediately the student has given a response. However if the feedback is extensive or requires the use of rich text or graphics, an *explanation question* is usually the preferred route. This appears on the screen separately after the response has been given.

Figure 2: Question types

1. Multiple choice
2. Multiple response
3. Push button
4. Hot spot
5. Text match
6. Numeric
7. Selection
8. Explanation question

We chose to give as much feedback as possible when the students were attempting the practice questions. If a response was correct, it was marked with a tick; if it was wrong, an indication of the correct response(s) was given, together with an explanation. During the official tests, it was felt that some feedback would be helpful, so an indication of the correct response(s) was always shown (but no explanation was added).

The QM suite has three main components: **Designer, Presenter** and **Reporter**. **Designer** is the tool which provides templates for the different types of question. It also contains the control information which determines the type of feedback given to students, the sequence in which the questions are asked and whether the response options are shuffled. **Presenter** actually delivers the test to the student and provides the feedback. It has a passworded entry and can restrict the length of time available for the test. **Reporter** contains the answer files of individual students. It can be used to determine who was taking a particular test and when it was taken. It can be used to identify students who were experiencing difficulty. In addition **Reporter** carries out statistical analyses of responses to individual questions by students which gives the *facility* and *discrimination value* of questions. These can be used to 'weed out' inappropriate questions and to refine the test.

An interim evaluation of the module

The new Clinical Science course has now been completed by two cohorts of students. There were 14 in the first intake and 13 in the second one. The majority of students entering the module had passed two or more subjects at GCE A-level (not necessarily including chemistry). The qualifications of other students included the BTEC National Diploma and the Irish Leaving Certificate.

Student feedback

All but one of the 14 students completed and returned an anonymous questionnaire at the end of the module.

From this we drew the following conclusions:

- two-thirds of the students thought this style of teaching was better or much better than lectures. None thought it was worse than lectures. All but one of the students were either satisfied or very satisfied with the module. The structure and organisation of the module was also favourably regarded by students.
- **all** students thought that practice questions with feedback and the regular tests helped their learning.
- students did not find the volume of work excessive (although there was a significant increase compared to lecture-based modules and on average students spent more than the nominal expected commitment of 13 hours per week).
- 71% of students said that they had received help from other members of the class whereas 57% said that they had given help to other students, showing that substantial peer assisted learning had occurred.

Student performance

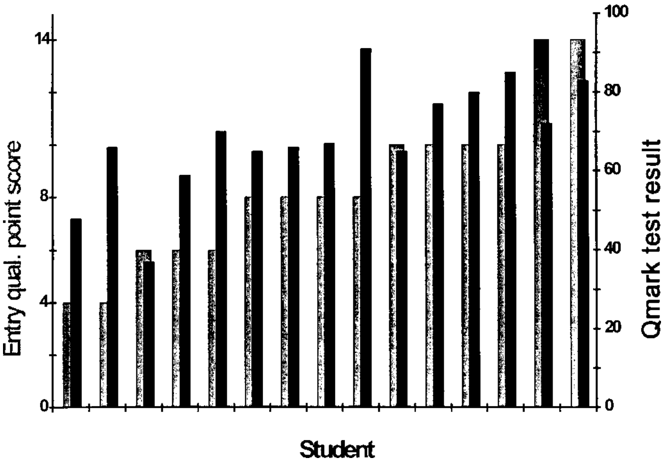
All students obtained a rather lower mark in the end-of-module examination than they did in the within-module tests, and the two marks showed only weak correlation. Given the immediacy and limited coverage of the within-module tests, this is not surprising, and we do not believe it invalidates either form of assessment.

The combined mark varied from 40% to over 80%, a mark distribution which compares favourably with other modules. The second cohort obtained a lower average mark than the first cohort and this was consistent with their relative performance in traditionally taught modules.

The end-of-module examination required the student to attempt four questions out of a possible six, three of which were essay style, and the remainder semi-structured. We noted that some of the students (particularly the BTEC entrants) seemed to find the formal examination more difficult; similar scores were achieved in the Introductory Physics examination.

We have compared the entrance qualifications of the students in the first cohort with their final mark (see Figure 3). The entrance qualification was obtained by adding the A-level point scores in biology and chemistry (when this had been taken) or by using recognised equivalent scores for entrants with other qualifications. Figure 3 shows that the students entered the course with a wide range of achievement. In general those with the weakest background showed the greatest relative improvement, and those with average backgrounds remained about the same. The two students with the highest entry qualifications had been advised to concentrate on other modules and this probably explained their relatively poor performance. From this analysis we concluded that the students with low entry scores benefited from the opportunity to work at their own pace, and that this helped to reduce the inhomogeneity of the group before they progressed to more advanced modules.

Figure 3: Comparison of QMark test results and point scores of entry qualifications in chemistry and biology



Tutors' input

A significant feature of this module is that the normal weekly contact time of six hours per week was reduced to two hours. This is a significant saving of staff time, and also reduces the pressure on teaching accommodation.

Our reflective evaluation of our contribution to the learning environment is based on our analysis of the amount of interaction with students and the quality of the discussion during the weekly classes. We concluded that our input (in two hours) was more effective than is possible in the six hours of a traditional lecture-based module, and we relate this to Boothroyd's point[7] that we were using our time to help the students with the higher order aspects of learning.

The key elements of the module have now been incorporated into two laboratory-based courses, year 2 of HND applied Biology and year 1 of BSc applied Biochemical Sciences for a total of 60 students. The attitude of these students has been very positive and their overall performance has been at least as good as previous cohorts. We are therefore satisfied that this module is appropriate for students with a range of backgrounds and that it serves the needs of a range of courses. We conclude that requiring students to take more responsibility for their learning in introductory courses provides a sound foundation for future study.

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