The Teaching of Basic Chemistry to University Foundation Students

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Introduction

With the massive expansion in higher education in the UK has come not only greater numbers but a wider range of backgrounds, which for degree courses include: GNVQ, Access courses (through FE colleges) and non-traditional A-level subject combinations. For pre-degree courses, the entry qualifications of students are even wider, with many mature students claiming little or no previous science background.

Such a wide spectrum of entry qualifications means that fewer assumptions can be made in introductory courses; some students entering university in 1997 would have been loosely described as 'middle band' school pupils ten years ago, and this complicates any pedagogic action which seeks to improve the chance of their success. Nevertheless, in order to maintain the present flow of students into higher education, the needs of this group must be urgently addressed. We suggest that there are three main areas which reduce achievement by foundation students. The first is calculations, the second is that of language and the third is student motivation. Here we give examples of each of these drawn from our own studies.

Calculations involving concentrations

Calculations involving solution concentrations, often limited to 1:1 reactant ratio only[1], are first introduced to many students in GCSE chemistry (GCSE balanced science students may never experience these calculations[2]). Typical examination questions, presumably designed to be helpful to the student, lead the student through the calculation in many stages[3] such as:

- working out the molecular mass of a reactant;
- calculating its amount;
- finding its concentration;
- writing a balanced equation;
- working out the equivalent amount of a second reactant (using the stoichiometry);
- determining an average titre and eventually;
- finding the concentration of the second reactant.

We find that many students continue to solve problems in this manner (a 'linear' approach) when they arrive at university. We analysed the calculations submitted by a cohort of 70 first year students after a practical in which they were required to standardise a solution of potassium permanganate, using a standard solution of iron ammonium sulphate which they had prepared themselves. Few calculations were correct; 69% of solutions were incorrect in one or more major respects and recalculation and resubmission was required. In the vast majority of these deficient solutions, students adopted the linear approach, but missed out certain key steps in the calculation. Seemingly oblivious to their error, they carried on and inevitably arrived at the wrong answer.

Correct calculations involving the use of the linear method requires the student to hold in his or her memory the steps in the calculation *in a fixed order*. The student also has to remember the correct procedure for each step in the calculation. One explanation of the difficulties encountered is that the 'working memory' space[4] required for these operations may not be readily available to weaker students. Certainly, the common '*missed step*' type of errors suggest this. For this reason, we have experimented with replacing the linear approach with fewer steps which involve one set of substitutions[5,6]. This approach was adopted very reluctantly, and mainly in the throes of desperation after repeated tutorials (albeit with larger groups than we would like) produced a disappointing level of success which we had never previously experienced in HE. Using the '*substitution method*' produced fewer mistakes and perhaps confirmed what many good school teachers already knew – that fewer steps (with or without full understanding) yields success and confidence, and that success produces a 'feedback loop' in which students are more likely to appreciate alternative strategies in the future.

Watch your language! – language and the mature student

It is popularly believed that science is a purely logical subject, in which language is used consistently and clearly. Several examples, discussed below, illustrate that this is not always true.

Our first example is of the topic *acids*. In ten commonly used textbooks examined by the authors, acids are defined in two distinct ways, as illustrated by this quotation from the highly acclaimed textbook by Kask and Rawn[7]:

"Some substances produce H^+ ions when dissolved in water. Such substances are called *acids*." Then three lines later, "For example, when gaseous hydrogen chloride, HCl, is dissolved in water, it forms *hydrochloric acid*. (Our italics).

This paragraph defines acids as substances which react with water producing H^+, and also as the solutions that are produced when acids react with water! Several more confident mature students have pointed out this and similar apparent contradictions, and we conclude that even '*straightforward* *definitions*' may seem illogical to the more searching mature student.

In the case of acids, the apparent illogical position has arisen because the products of the reaction of acids with water were known long before the acids themselves, and such products have been known as acids (*'sour tasting'*) for centuries. In school, these definitions/descriptions (and more elaborate ones) about acids are developed separately over time, and are seen as a progression in the complexity of the theoretical base. On the other hand, the mature student who has no previous experience of the subject will be exposed to both definitions *simultaneously*, and the more seriously the issue is examined, the more confused he or she may become. In summary, the *intelligent response* of many able mature students may bring with it problems which are of minimal importance to students who have absorbed the *'culture'* and language of the science through the longer (traditional) school route.

The second example concerning language concerns the topic of oxidation and reduction, where we believe that attempts to simplify the issues can actually lead to more confusion. For example, standard electrode potentials are often used to answer this type of question: 'Can zinc react with copper(II) ions?' The question is often stated in this brief form, but strictly it makes little sense because it does not inform the student of the proposed products of the reaction. Intelligent students are quickly thrashing about searching in forbidding looking tables of half-reactions for possible products, each of which is associated with different electrode potentials. The more complete question 'Can zinc react with copper(II) ions to produce zinc(II) ions and copper metal', although rarely stated in this way, makes the task more explicit, and is less confusing.

These two examples serve to highlight that careful consideration of language and context is important in HE. This has been well studied in schools[8]. For example, the polysemous nature of common words (e.g. matter, pure, scale) has been considered by Tateson[9].

Motivation

It is a false assumption that students in higher education are always highly motivated. One feature that distinguishes high performing students from low performing students is that the former are much more able and willing to work on their own. This point has been raised in a CNAA review[10]; this was hardly worthy of discussion in the past, which dramatically illustrates how the intake into higher education has changed over the last ten years.

For financial reasons, higher education cannot mimic the level of individual attention that students receive in school. Nor is this educationally desirable, since the ability to work independently is usually regarded as one of the qualitative distinctions (other than intellectual difficulty of work) between school (or FE) and HE. Indeed, we *regard it as axiomatic that whatever strategy is employed in HE, even foundation students cannot be allowed to remain passive partners in learning.*

One of the most difficult tasks facing any teacher is to persuade students to take responsibility for their own learning[11]. We also recognise that one of the most important criteria in establishing student motivation, is a recognition on the behalf of a student that the work to be completed in a course is *relevant to their specialist degree scheme*. Accordingly, it is important that the lecturer conveys the reasons for such relevance to the students from the first lecture. In our survey of foundation-level students taken in 1997, over 86% of students described chemistry as 'useful' or 'very useful' in relation to their chosen degree. This degree of unanimity was surprising, though comforting !

Educational research is now providing pedagogically useful information on the motivation and needs of HE students. In the past, motivation was regarded as a fixed characteristic inherent in students, but we now appreciate that motivation is partly determined by encouragement and a belief that they (the student) *'are able to succeed with reasonable effort'*[12]. The effect of such studies is to emphasise that, provided the course has been tailored to the needs of the student, each objective within the course should become a *'can do'* (and not a *'can't do'*) obstacle. Foundation courses also have the advantage that differentiation is less important at this stage in the degree scheme, and assessments reflect this.

What are the problems? The most obvious one, supported by previous experience, is that weak students do not always seem able to discipline themselves to use the support material. Another difficulty of a very different kind is that the lack of individual interaction with students in a large group (supported, in all probability by an inadequate number of tutorials) reduces the opportunity for the teacher to find out, at first-hand, *'what the student understands by certain terms - as opposed to what we would like them to understand'* [13]. *Central to this strategy is the process of defining scientific terms and their relationship to the previous stock of ideas acquired by the student. This is no trivial task.*

Foundation chemistry at Glamorgan

Teaching on foundation courses has forced us to remodel our ideas of university teaching. Some of the ideas we use have been imported from educational research designed for schools. Many of our conclusions are based upon experience. This experience has led us to adopt the following principles in designing our one-semester foundation chemistry course at Glamorgan;

- using the lectures for the explanation of key points only, with no 'content overloading' and giving only one example of each problem;
- making exact references to an open-learning text *dedicated to the requirements of the course*;
- convincing students that the support material is *an extension* of the lecture and not an optional extra;
- making students aware of the need to amplify their experience of the subject by studying named numerical and chemically based questions in their own time;
- assessing by several multiple-choice tests and coupled with one or two sets of (more challenging) homework problems;

- realising that *how* one teaches is as important as *what* one teaches.

References

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