Preparing the Mind of the Learner

PAPER

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For a period of two years, examination performance in an introductory course in university chemistry was found not to be correlated with entry qualifications of the students in chemistry. For the next three years, examination performance did seem to be related to entry qualifications. The only factor that was found which might account for this was the use of pre-lectures which were employed over the first two years but were no longer in operation over the subsequent three years. On this basis, it is suggested that pre-lectures may be a useful tool in enabling students to make more sense of lectures, the effect being particularly important for students whose background in chemistry is less than adequate.

Introduction

In 1968, Ausubel made the comment: *"If I had to reduce all of educational psychology to just one principle, I would say this: the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly"* [1]. This bold assertion has been supported by subsequent work. Thus, for example, Johnstone and Su[2] showed that students could have problems in lectures when lecturers assumed prior knowledge which, in fact, was absent or had been forgotten. Ebenezer[3] applied Ausubel's idea in the development of concepts in chemistry. Johnstone[4] developed the ideas further in suggesting a set of educational principles (known as 'Ten Commandments') for learning. Among these were the statements: "What you learn is controlled by what you already know" and "If learning is to be meaningful, it has to link on to existing knowledge and skills, enriching and extending both."

While appropriate knowledge and skills must be present in the mind of the learner, it is also important to recognise that they must be accessible (able to be retrieved in a meaningful form) at the time when new material is presented. It is also important that the new material must be presented in a manner consistent with the way the previous knowledge and skills have been laid down in the long term memory. It is, therefore, important that the minds of the students are prepared for lectures if the learning is to be meaningful for the students[5].

It is not easy to put these general principles into practice since students will come to lectures with a wide variety of background knowledge. In some cases, previous learning in chemistry may have led to an incomplete or incorrect grasp of concepts[6]. For other students, ideas once known and understood may not have been used for many months, making it difficult to retrieve them from long term memory. In order for effective learning to occur, background knowledge and understanding must not only be present, but stored in such a way that it is accessible and understood correctly. These principles lie behind the idea of the pre-lecture. The pre-lecture can be described as an activity carried out before a block of lectures, designed to ensure that the essential background knowledge is established and is accessible so that new learning can be built up on a sound foundation. Kristine[7] reported a system of pre-lecture assignments, involving preview reading and review, the aim being to encourage the development of study skills. A decision in this university to develop a new introductory course provided an opportunity to introduce pre-lectures. These were subsequently discontinued and this paper describes our observations on the effect on the students of both introducing and discontinuing pre-lectures.

The general chemistry experience

Before 1993-94, students studying chemistry at level-1 (of a Scottish four year degree) all followed the same course. The class included those who were planning to pursue chemistry as their main subject along with those who were required to take a first year chemistry course as a support for some other discipline and those who were taking the course merely to complete their first year curriculum. Since students typically take three subjects during their first year, the level-1 chemistry course was designed to occupy one third of the workload and included about 100 hours of lectures. The level of the course was appropriate for students who had obtained a pass in Chemistry at Higher Grade in the Scottish Certificate of Education.

Over a number of years, the characteristics of the first year entry changed. Numbers increased to around 600 – 800, and the range of entry qualifications became much broader and included some with no formal chemistry qualification at all, their entry to university being based on other qualifications. It was therefore decided to form two classes for the session 1993-94. The majority of students, those with qualifications in Scottish Higher (usually at Grade C or above) or in the Scottish Certificate of Sixth Year Studies (CSYS) would take the essentially unchanged level-1 Chemistry Course, now named Chemistry 1. The less well qualified students would take a new course designed to allow those who passed to proceed to the level-2 Chemistry Course.

The new course is called General Chemistry. The aim was to meet the needs of students for whom a career in chemistry was a less likely option and who, in general, were less qualified in chemistry. The entry qualifications of the students in

General Chemistry ranged from those who have passed Chemistry at the Scottish Higher Grade (occasionally, with a pass at the Scottish Certificate of Sixth Year Studies as well), to those who had indicated no formal chemistry qualification at all, their entry to the university being based on qualifications in other subjects. Since surveys of students showed that the majority were taking the course to fulfil faculty requirements, commitment and motivation were generally low.

The General Chemistry course was planned according to the ten educational principles, described in detail elsewhere[4]. Pre-lectures were introduced primarily to address the principle which states that learning depends on previous knowledge. In 1993-94, 8 lecture courses had an associated pre-lecture. The pre-lecture occupied one timetable lecture slot, the total lecture time thus being reduced by nearly 10%. In 1994-95, 6 pre-lectures were retained. In 1995-96, pre-lectures were discontinued, the time being given over to extra lectures. The way the course operated and the performance of the students was monitored in some detail over a period of five years and is still being monitored.

A pre-lecture can take many forms. In the General Chemistry course, the following procedure was adopted. Working in an ordinary lecture theatre, the pre-lecture involved a short test (multiple choice and very short answers) which sought to check on necessary background knowledge. The students marked this for themselves. The test and marking took less than 15 minutes. Their test performance provided the students with some evidence about the level of their background knowledge and understanding.

On this basis they were invited to see themselves as 'needing help' or 'willing to offer help' and the class was re-organised to form pairs or trios to allow the 'helping' students to interact with those needing help. In this way, support was available for those students in need of help to understand the background knowledge that would enable them to make sense of the lecture course. Those able to offer help assisted in this process of teaching, and, by the very act of teaching others, they themselves were assisted in ensuring that ideas were grasped clearly and correctly.This reflects another of the 'Ten Commandments'[4].The lecturer,supported by a demonstrator, was on hand to offer assistance as required.

The main part of the pre-lecture involved the students working with a series of short exercises which covered material that was considered an important background in allowing the students to make sense of the lecture course to follow.The exercises encouraged discussion within the pairs and trios.For example, in the first pre-lecture, topics covered included the fundamental ideas of states of matter, elements and compounds, chemical and physical changes. Another pre-lecture covered the ideas of models of matter, unit cancellation, and the nature of the mole.

Results

Student performance in the Chemistry-1 Course, which never included pre-lectures, generally correlates well with their entry qualification.The data for 1994-95 are shown in Table 1.The Certificate of Sixth Year Studies (CSYS) is a one year course taken by some students in the year after the Higher Grade course. A pass in any grade at CSYS is generally regarded as approximately equivalent to one grade higher than the same letter grade at Higher. Thus a B in CSYS is approximately equivalent to an A at Higher. Table 1 shows that the average examination mark for students with a particular grade decreases with their entry qualification.

Identical trends were seen in all years for which data are available.

Table 1: Correlation between entry qualification and average mark in Chemistry-1.

Entry Qualification	*Pass Grade*	*Average Mark (%) for 1994-95*
Certificate of Sixth	A	76
Year Studies (CSYS)	B	59
	C	44
	D	36
Higher Grade	A	51
	B	39
	C	31

In looking at General Chemistry, we tested the effect of entry qualification on exam performance by dividing the students into two roughly equal sized groups and comparing their examination performance. Group 1 included all students with a pass in chemistry at Grade C or better in Scottish Highers. Group 2 included all students with a lower entrance qualification. With the relatively small numbers of students taking General Chemistry, we could not justify dividing the class into more groups. The results for the first five years of the General Chemistry Course are shown in Table 2. As previously described, the pre-lectures were discontinued after the first two years.

Table 2 shows the difference in the average examination mark obtained by each of the two groups; since there was an examination in January and in June, the difference in average mark is shown for both individual exams and for the combined mark. The t-test was used to test whether these differences are significant. As Table 2 shows, there was no difference between the two groups when the pre-lectures were in use. When pre-lectures were discontinued in 1995, the difference between the two groups became significant.

Having shown that there was no difference between the two groups of students during the two years when pre-lectures were in use, we felt justified in combining both years and dividing this combined sample into four groups. The groups were assigned as follows:

- Scottish Higher Grade pass in Chemistry (almost all at Grade C);
- Scottish Standard Grade pass in Chemistry (approximately equivalent to GCSE);

Table 2: Difference in Average Mark in General Chemistry for groups classified by entrance qualification

Year	*Number of Pre-lectures*	*Total Number of Students*	*Difference (%) (January Exams)*	*Difference (%) (June Exams)*	*Average Difference (%)*
1993-4	8	110	3.1	1.1	2.1
1994-5	6	180	0.2	0.2	0.2
1995-6	0	169	7.2[1]	9.2[1]	8.2[1]
1996-7	0	163	8.3[1]	4.2	6.3[2]
1997-8	0	229	2.9	7.9[1]	5.4[3]

1 These differences are statistically significant (t-test, two-tailed, unrelated): $p < 0.001$
2 This difference is statistically significant (t-test, two-tailed, unrelated): $p < 0.01$
3 This difference is statistically significant (t-test, two-tailed, unrelated): $p < 0.05$

Table 3: Average Mark in General Chemistry: effect of pre-lectures

Entry Qualification	*Average Mark (%) for sessions 1993-94 and 1994-95 (pre-lectures)*	*Average Mark (%) for sessions 1995-1996, 1996-97 and 1997-98 (no pre-lectures)*
Scottish Higher Grade	49 (N = 137)	47 (N = 244)
Scottish Standard Grade [1]	50 (N = 44)	37 (N = 70)
Alternative qualification [2]	49 (N = 44)	42 (N = 63)
No formal qualification	45 (N = 31)	42 (N = 56)

1 Approximately equivalent to GCSE
2 Mainly those with entry through Access courses or modules.

- Qualifications in Chemistry based on Access courses;
- No formal qualification in Chemistry.

These four main groups include the majority of students. However a few students with unusual qualifications (e.g. from overseas) are not included in this analysis.

Table 3 shows the average examination obtained by each of these four groups. For comparison, Table 3 also shows the average marks for the same groups of students during the three years when the pre-lectures were discontinued (1995-96, 96-97, 97-98). Pre-lectures appear to have made a marked difference to those students with Scottish Standard Grade, and a smaller difference to those with alternative qualifications.

Taken together, Tables 2 and 3 provide strong evidence that the pre-lectures make a significant contribution to the creation of a course which provides all students with a reasonably equal opportunity to perform well.

Discussion

The pattern of results is surprising. Intuitively, it seems unlikely that what appears to be a small change in teaching could make this impact. However, it must be noted that the pre-lectures amounted to approaching 10% of the total time allocated for lectures, a sizeable proportion of the teaching input. Nonetheless, we examined as many other factors as possible to see whether any alternative explanation was likely.

A wide diversity of factors was examined in the first two years: preferred learning styles (following the Perry model[8] and extent of field dependence[9]), gender of students, whether they stayed at home or away from home, personality characteristics (eg extent of extroversion, extent of neuroticism), maturity, qualifications in mathematics. None of these correlated with examination performance.

An examination of other features of course organisation showed that other changes had occurred over the five year period but none had taken place specifically between 1994-95 and 1995-96. Although the size of the group had risen over the five year period, the composition of the class in terms of the proportions of students with various entry qualifications showed no discontinuity after year 2 and, indeed, no trend over the five year period. Looking at common questions in successive examinations showed a very slight deterioration in overall performance over the five year period.

It is often tempting to try to cram in more material in order to improve performance. The study by Johnstone and Su[2] of student habits in lectures shows the folly of this approach. The observations made on this course would seem to suggest that reducing the amount of material might be advantageous if the time released was used to prepare the minds of the students to make more complete sense of the new material offered. Garratt[10] claims that there is some evidence for the proposition that covering less material results in more total learning.

The use of pre-lectures might also, of course, be having more subtle effects. The confidence and motivation of more poorly qualified students will almost certainly be enhanced by learning experiences where their weaknesses were being taken into consideration. Motivation has been shown to be very important in influencing performance[11]. In addition, the use of pre-lectures could also be having a subconscious effect on the lecturers by heightening their sensitivity in checking the pre-knowledge of the students during the presentation of new material.

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Undergraduate Students' Understanding of Enthalpy Change

PAPER

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The study described in this paper is an investigation into the conceptions held about chemical thermodynamics by first year chemistry undergraduate students. Twenty students were interviewed on two occasions, each for about one hour and asked to explain temperature changes in three simple chemical reactions. The first interview sought to identify knowledge retained from A-level; the second interview followed a lecture course on chemical thermodynamics. Students' conceptions about enthalpy change are described and examples of students statements are given; it is clear that students come to the university with a very limited understanding of enthalpy change and have no knowledge of pV work. The impact of the lecture course on their conceptions is discussed; most students still held the same conceptions about enthalpy change although there was more awareness of pV work. Some quantitative information is given but the qualitative data show the range and variety of the alternative conceptions. Finally, the implications of the findings on the teaching of elementary chemical thermodynamics is discussed.

Introduction

This paper reports on part of a larger study which arose out of a concern of a chemistry department about the effectiveness of a first year course of chemical thermodynamics for undergraduate chemistry students. Although students were performing reasonably well in end of module examinations, informal discussion with tutors indicated that their understanding of basic thermodynamic concepts seemed weak. Similar views have been expressed in the literature[1,2]. The result is that, for many students, the study of thermodynamics is regarded as a chore whose equations are to be learned by rote in order to do calculations and to pass examinations.

A possible cause of the problem is a mismatch between the assumptions made by the teaching staff of the students' prior knowledge and understanding and the conceptions actually held by the students. Many previous studies of students' understandings of scientific concepts[3,4,5] have shown that students often hold conceptions which are different from the accepted science concepts and that when students construct new meanings, they are influenced by their own pre-existing (and often incorrect) conceptions. In this report, the term 'concept' is reserved for an accepted statement; the term 'conception' is used to refer to an individual's version of a concept and may be correct or not. The term 'alternative conception' is used to describe all conceptions that differ from the accepted version. Such alternative conceptions range from those that are very different from the accepted view to those that are merely incomplete.