[K2] Teaching undergraduates to think: from parrots to professionals

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Abstract

There is a need in chemical education to provide students with open ended, creative problem solving activities. Critical thinking exercises and problem solving case studies have being developed in order to provide students with a 'real' context to extend their knowledge of chemistry, to develop intellectual or 'thinking' skills and practise a range of transferable skills. The nature of the activities involved ensures that, in order to complete the case study, students must use a variety of subject specific and transferable skills.

Introduction

Employers have long been urging the Higher Education sector to produce graduates with a range of key skills that would make them more immediately effective in the world of work. Several reports (e.g. Finer, 1996) have highlighted particularly communication skills, team working, numeracy, use of IT and learning to learn as highly desirable qualities in a graduate. This view has also been highlighted as being particularly important in a report by the LGC (Fleming, 1994). Following a comprehensive survey carried out by the LGC (Milgrom, 1993), the report states that employers' overwhelming concern was with the graduates' ability to apply appropriate theory and laboratory techniques to practical problems. In particular, graduates should be able to evaluate a specific problem, identify appropriate theory, methods and techniques that can provide a cost-effective and reliable solution, and ensure that this solution is implemented in accordance with rigorous quality or regulatory regimes. Good interpersonal skills were identified as being crucial to allow analysts to work effectively in a team and to evaluate problems jointly with clients.

So, in order to produce graduates who can operate in the workplace as professionals we need to go much further than just ensuring that they have a sound knowledge of their discipline. We must produce graduates who can think critically, have an analytical approach, can interpret data and information, tackle unfamiliar and open-ended problems and apply all that chemical knowledge that they have acquired. In addition, the modern graduate must master a range of 'professional' or key skills. These include communication, team working skills, time management, information management and independent learning.

The Challenge

What is missing from the traditional approach to the chemistry curriculum that would enable students to develop these intellectual and personal skills and capabilities? In order

to enhance the qualities of the chemistry graduate we need to provide opportunities to develop advanced problem solving skills, a range of key skills and an appreciation of the range of applications within which the professional chemist works. Problem solving activities can provide the vehicle for achieving this. Students should begin to tackle unfamiliar and open-ended activities that allow some degree of flexibility and creativity.

Johnstone (1993) has categorised problem solving activities and identified their characteristics according to whether the problem is familiar, has well defined aims and has a complete data set. Most of the problems that students encounter during traditional chemistry teaching and learning activities are firmly rooted in the lowest type of problems. An attempt was made to produce novel problems for chemistry undergraduates in the 1999 publication 'A Question of Chemistry' (Garratt *et al*, 1999). In this book problems of several different types were presented. The categories used were: 'understanding argument', 'constructing argument', 'critical reading', 'using judgement' and 'reference trails'. The nature of the problems meant that their styles would be unfamiliar to most students as they were generally non-numerical, open-ended and without a single correct solution.

An example of a problem from the 'using judgement' chapter is given here. It is based on the requirement to carry out a 'back of the envelope' calculation in order to obtain a rough answer that gives the student some insight into analytical processes and scale of analyses.

> *The proverbial expression 'looking for a needle in a haystack' might be used by scientists trying to detect or identify traces of compounds. If there is one needle in a haystack, estimate its concentration in parts per 10^n on a weight or volume basis.*

When problems of this type are used in classes of students, in addition to developing their range of thinking and problem solving skills, it is immediately obvious that other 'key' skills and competencies are being developed. The students have to formulate and defend ideas, communicate their ideas to each other clearly, and they have something to discuss for which they are entitled to hold and defend an opinion that may differ from that of the tutor. There is no longer a single correct answer, so students have to realise that answers are not always right or wrong.

I have become convinced that the best way to address the skills development agenda is through problem solving activities. Those in 'A Question of Chemistry' are fairly short, so they can be worked on within a tutorial session. If the problem-solving activities were extended so that they required students to learn some chemistry content in order to make progress and, if the problems were carefully developed, these should then stimulate students to expand their knowledge and develop a wide range of professional skills. This reasoning has led to the development of problem solving case studies. They are related to applications or real contexts, provide incomplete or excessive data, require independent learning, evaluation of data and information and do not lead to a single 'correct' answer.

Case studies have a long history in many subject areas and their value within chemistry has long been recognised (Belt *et al*, 1998, and Overton, 2001).

A case study should:

- involve the learning of chemistry either by building on and showing the relevance of prior learning or by requiring students to learn independently in order to tackle the case

- be active in style
- involve a work-related context
- involve the development of personal skills
- encourage reflective learning
- have clear learning objectives for students

Case studies require students to work both individually and as part of a team to solve an extended problem. Each case study is flexible enough to be used in a variety of different teaching situations and each has been designed to encourage the development of different transferable skills. For each case study, students work in small groups and the contact time is ca. 4-6 hours with students usually spend 6-12 hours in associated independent study. The case studies offer a number of opportunities for assessment depending on the learning outcomes set by the tutor.

The Titan Project

For this case study (Summerfield *et al*, 2002), students adopt the role of the management team of a titanium dioxide plant empowered to make recommendations on the future of the site. The case study encourages students to consider industrial chemistry in a broad context of the associated safety, environmental, economic and social issues. Some of the case studies are outlines here.

The Pale Horse

In this case (Overton *et al*, 2002), the students act as the investigation team for a (fictitious) suspicious death. The evidence is gradually presented in reports from attending police officers, an investigating officer, a forensic medical examiner, a scene of crimes officer (SOCO) and a forensic scientist. From these, students select samples for analysis together with the corresponding analytical methods. By consideration of the results from these analyses, the students are able to identify the cause of death, the manner in which the poison was administered, and the role of analytical chemistry in solving the case.

Conclusion

These case studies have been piloted with students ranging from undergraduate to masters level study at over a dozen UK universities. The staff and student feedback has been very positive. It is noteworthy that the enthusiasm and engagement of the students swiftly increases as the case studies progress, presumably due to an increased familiarity with the approach and perhaps due to a greater involvement in decision-making processes. Additional feedback from students shows that the case studies not only provide them with the opportunity to develop their knowledge of analytical chemistry, but serve to increase their awareness of their transferable skills and capabilities.

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