Using Case Studies to Develop Key Skills in Chemists: A Preliminary Account

COMMUNICATION

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A series of case studies is being written with the aim of developing new and existing skills in chemists for employment. The development of the first of these case studies is described together with an overview of content and structure. Group work, tutor input (including assessment) and student skills profiling are discussed in more detail. These case studies are complementary to other skills based exercises and could be easily incorporated into other BSc Chemistry based courses. Preliminary observations made with Stage 2 Chemistry and PhD students indicate that these case studies can provide an enjoyable and effective means to skills development within a chemical context.

Introduction

A number of reports identify several key skills as being important to employers, but not well developed in recent graduates[e.g. 1-5]. The recent report of the National Committee of Inquiry into Higher Education[6] specifically identifies the skills of communication, numeracy, use of information technology, and learning how to learn as "*necessary outcomes of all higher education programmes*". The report also envisages that students should be put "*at the centre of the process of teaching and learning*", and recommends that "*all institutions of higher education give high priority to developing and implementing learning and teaching strategies which focus on the promotion of students' learning.*"

Various strategies have been developed within the discipline of chemistry for achieving these aims. Some involve discipline related activities,[7] others may be discipline-independent.[8] Maskill and Race[9] have taken an approach which lies between these extremes. Our aim has been to identify a wider range of skills than those defined by Dearing,[6] and to address as many of them as possible within a series of case studies.

Case studies have a long history in business and management courses, and their potential value in chemistry courses has been recognised for many years[e.g. 10-13]. A case study exercise is typically based on a real event which provides a context within which a decision has to be made. The aim of the exercise is to develop a mode of thinking, working and communicating, and this is best done by tackling a problem where there is no uniquely 'correct' answer. This paper is a preliminary account of the development and use of one such case study which is suitable for use in undergraduate chemistry or chemistry-related courses.

Identification of a suitable topic

We wished to develop a case study for use by final year BSc students which would require them to draw on their chemical knowledge, apply it in a context relevant to the environmental theme of their course, and provide a vehicle for them to practice a wide range of personal and professional skills. For practical reasons, the chosen study needed to be one for which we had ready access to a large amount of relevant data. In consultation with the Environment Agency (EA), we identified the case of the disused Wheal Jane tin mine in Cornwall. Briefly, the case is this.

In 1991, rising water levels in the disused tin mine resulted in the rupture of a plug in an underground adit causing millions of gallons of highly acidic water to be released into the neighbouring Carnon river and estuary. The underlying geology and acidic water meant that the discharge contained large concentrations of heavy metals which were of both short and long term environmental concern. A monitoring and treatment system therefore needed to be put in place that would satisfy both short and long term needs.

This makes a good case study because the possible solutions to the problem involve thinking more broadly than about chemistry alone, and the chemistry is relatively straight forward; furthermore the overall problem can be broken down into smaller tasks, so that none are overwhelmingly daunting. A complete solution involves research into various monitoring methods and treatment systems, calculations of a life expectancy for a treatment process, consideration of options for disposal and potential recovery of the metals concerned. This work involves a large amount of information retrieval from a variety of sources (including computer based searches and communication with companies), evaluation of information, familiarisation with new topics (e.g. legislation) and developing working equations for parameters that present difficulties in measurement (the volume of a metal precipitate in this case). Clearly, it is important that students have access to the information that is required. In the case of Wheal Jane, much of this is in the public domain. Other, specific numerical data has been provided by the Environment Agency, who also represent an invaluable general information source for students to make contact with at the outset.

Our initial analysis of the problem suggested both specific skills which should be addressed and activities through which they could be practised. These are listed in Table 1.[6]

Table 1: Summary of main skills and specific activities

Main skills	Specific activities
Group working	Discussions, minute taking, brainstorming, feeding back, division of tasks
Communication	Oral presentations of varying lengths and complexity to different audiences, report writing, inter-personal development
Critical thinking	Linking chemistry with other issues (cross-disciplinary thinking); evaluation of information
Independence	Individual judgement; taking responsibility for decision making,
Time management	Planning, prioritising and working to tight deadlines
Information retrieval	Collection and classification of information
Data treatment	Manipulation and evaluation of information,; undirected numerical and chemical analysis; computing skills
Commerce	Costing; evaluation of market forces
Legislation	Evaluation of Environmental law and EU directives

Procedure

The case study consists of four tasks which are tackled over a 5-10 week period by students working in groups of 4-6. The overall structure is shown in Figure 1.The 5 formal timetabled sessions are held at intervals of 1-2 weeks. Each session is led by a tutor.Since most of the session time is taken up with oral presentations and questions, the length of time required for each session tends to increase proportionally with the number of groups. For 2 - 3 groups most sessions are 1-1.5 hours.

The initial scenario is provided in the form of a newspaper article from a local newspaper.This not only introduces the project in a brief and understandable format, but also encourages students to begin to think about how they may present technical information to non-experts (see Session 5).

Groups are provided with written instructions detailing the tasks to be completed before the next session. Students are expected to manage their own time during this period, though e-mail help is available to them. Each is expected to devote about 6 hours to each task, some of which will be working within the group and some performing individual tasks agreed by the group.

In sessions 2-4, the results of the tasks are presented in the form of both written reports and oral presentations of specified lengths.Time is also reserved for discussion and an introduction to the following task. The discussion is divided between time for questions relating directly to the task and for a summary of the skills used, together with an evaluation of the effectiveness of these. This allows students to reflect on the work they have done and how they did it, which together, is a crucial part of the learning process.For the fifth session, all the tasks are brought together so that the written report provides an integrated technical solution to the

Figure 1: General timetable for the case study*

Session 1(30-40 mins)	Overall aims of the case study are described Students are divided into groups Newspaper article and Task 1 are given out
Task 1 (approx 6 hours)	Initial review during which student teams • research methods for analysing metal concentrations in water; • investigate treatment systems; recognise need for short and long term solutions; consider cheap and rapid solutions.
Session 2 (1 - 1.5 hours)	Oral presentation of Task 1 and submission of written report Discussion leading to agreement on recommended treatment system (temporary storage of contaminated water in nearby tailings dam, precipitation of metals by addition of lime). Further information and task 2 given out.
Task 2 (approx 6 hours)	Students are encouraged to recognise that the size of the collection dam is crucial, and that the long-term solution requires disposal of the metal deposit. Student teams • estimate volume of dam (carefully defining assumptions made); • investigate methods of disposal of precipitate.
Session 3 (1-1.5 hours)	Oral presentation of Task 2 and submission of written report Further information is given and discussed; conclusion drawn; Task 3 given
Task 3 (approx 6 hours)	Use two realistic scenarios to evaluate the proposed treatment system. Student teams • develop chemical and numerical equations, and hence calculate volume of deposited metal; • consider the viability of commercial recovery of selected metals
Session 4 (1-1.5 hours)	Oral presentation of Task and submission of written report Further information is given and discussed; conclusion drawn; Task 4 given out
Task 4 (approx 6 hours)	Integration of information collected from each task and preparation of final reports and presentations. Student teams • consider quantitatively how to reduce metal concentrations to legal limits; • consider environmental factors which control metal concentrations; • agree on reports and presentations.
Session 5 (2-2.5 hours)	Formal oral presentation to experts§ (30 minutes) Oral presentation to non-experts (10 minutes) Submission of final written report§

*Times indicated are for 2 - 3 groups

§ This includes the oral presentation and written report for Task 4 problem. The final session also includes both a technical presentation and one for to a non-expert (e.g. a concerned local resident or a work colleague who is not familiar with the details of the study).

Group work

This case study has been designed for use with 4-6 students in a team each contributing ca. 30 hours (including group work). For each task, the aims are clearly defined but the methodology is left to the group. Therefore, groups need to address questions such as 'What information are we going to need to know/use?' and 'How are we going to use the information once we have got it ?' Individual responsibilities can then be allocated. We stipulate that all group meetings should be formally minuted and the minutes made available. Since most students have had little or no experience of this activity, some guidelines (including a rationale) are given during the first session. Each meeting should have a chair and secretary, and these roles rotate amongst the students during the course of the case study. Our objective was partly to provide students with useful experience, and partly to provide us with an indication of how effectively the responsibilities were shared. Feedback from the students shows that this was a popular innovation.

Tutor input

Time

Our aim in writing this material was that it should be widely disseminated. This required us to prepare case studies which could be implemented with a minimal amount of preparation by lecturers. Since some of the tasks cover topics outside mainstream chemistry, we have included some guideline information as lecturer's notes for each of the tasks. Figure 2 lists the contents of the complete package. Since we are aiming principally for a well balanced scientific approach from the students, rather than necessarily looking for a 'right' answer, we believe that a set of key points or guidelines is sufficient to enable tutors to carry out a meaningful assessment. Tutor time should be in the region of 12-15 hours, most of which is spent in assessing in-session presentations and fixed length reports.

Figure 2: Contents of case study documentation

- Introduction and overall objectives
- Recommendations for the case study delivery
- Tutor's notes on assessments
- Assessment forms
- Student's notes on assessments
- Student's notes on groupwork and minute taking
- Notes on student skills profiling
- Student skills profiling form
- Newspaper article and Site report
- Registration form for updates

For each of tasks 1-4:

- A description of the task
- Indicative solutions
- Help-mail
- Further considerations

Providing help

It is important to provide student support outside the timetabled sessions. Some students may understand the task at the first reading, others may either be uncertain as to what exactly is required or simply not know how to go about tackling it. To make efficient use of tutor's time, we have opted against formal help sessions in favour of an e-mail based system termed 'Help-mail'. For cases where general help is required, we have tried to anticipate key problem-areas associated with each task and written a standard hints page. For cases where more specific help is required, students must request clearly what information is required. Ambiguous requests are met with ambiguous replies! The use of the e-mail system in this way goes part way to focusing students' minds and serves to illustrate an important area of time management since a response by a tutor (however helpful) to a request may not always be immediate.

Assessment

Groups are assessed against well defined criteria (e.g. clarity of presentations and reports, whether the specified task has been addressed fully, use of visual aids, time keeping).

We have not included an individual assessment component though we believe this to be an important feature to be developed in the future. We are aware of difficulties in doing this. For example, the monitoring of individuals directly in groups is impractical and many other methods (e.g. peer assessment) can be unsatisfactory particularly when employed in isolation. We are currently reviewing individual assessment methods and are favouring a combination approach, involving, for example, peer assessment combined with an analysis of the minutes from meetings. Assessment of the latter should provide students with a driving force for ensuring that these are a true reflection of each individual's contribution to the group effort. In addition, we are now developing a CAL package for each case study and liaising with industry to determine their methods for individual assessment.

Skills Profiling

We have introduced a procedure for skills profiling whereby each student completes a *pro forma* before starting the exercise. This outlines various key skills subdivided into categories. Three levels are defined for each category and the student identifies their own level and justifies this with an example. Progress is monitored by repeating this self-assessment after completion of the case study. It is not expected that improvement is observed in all categories but rather that over a period of time, a general progression is achieved. Extracts from our profiling form are shown in Figure 3[14].

Figure 3: Extract from student skills profiling document[10]

SKILL	*LEVEL ONE*	*LEVEL TWO*	*LEVEL THREE*	*Indicate your current level.*	*Justify your selection with a specific example*
Team working					
Accepting responsibility within a team	Take responsibility within a team for investigating a single simple aspect of a task.	Take responsibility within a team for collating and disseminating information relevant to a task.	Take responsibility within a team for collating information and recommending a selected course of action.	1	*I went to the library and compiled a list of all of the journals that cover analytical chemistry*
Communication skills					
Presentations (2) (experts)	Explain a scientific concept to an 'expert.	Deliver a scientific presentation using OHPs and answer questions directly related to the topic.	Deliver a multi media presentation of a scientific subject and answer a range of questions from experts.	2	*I have delivered a 10 minute summary of my final year project to my supervisor*
Data Manipulation & Information Technology					
Use of word processing, spreadsheets and graphics packages.	Use spreadsheets to create simple tables of data and plot graphs. Type and format short reports. Become familiar with graphics packages.	Perform complex mathematical functions within a spreadsheet. Prepare a full and complete report integrating a range of software.	Prepare a short 'stand alone' software presentation on a scientific problem.	1	*I write and format my laboratory reports in Microsoft Word. I can enter and plot simple x-y data in Excel, but I am unfamiliar with more complex manipulations. I have used chemdraw once for an assignment.*

Preliminary observations

Our Abandoned Mine case study has been tackled by one set of Stage 2 chemistry undergraduate students and one set of PhD students with presentations and report submissions taking place the following week. The undergraduate students received additional support in that, for 3 hours immediately following each timetabled session, a tutor running a laboratory class was available to deal with any problems which arose immediately. These sessions were useful in this initial trial in that they provided a useful means for obtaining rapid feedback on whether the appropriate level of guidance had been provided. The PhD students managed satisfactorily without this additional support; we believe that this better promotes independence, and in considering the long term, should be unnecessary for undergraduates. The observations from both groups are otherwise quite similar. Generally, students researched the information well and presented detailed and comprehensive accounts. In several cases, students had clearly spent more than of the recommended time in order to produce a high quality presentation or report. While this is not a criticism of the students *per se*, it serves to illustrate that it can be difficult within an academic setting, and with our current format, to ensure that fixed time constraints are kept to. Areas where students performed less well include justifications for answers, descriptions of assumptions made and quantitative considerations of opposing factors. Statements such as "*Several factors would need to be considered ….*" and "*Method X could never be used because it is expensive*" were common and indicate a superficial coverage rather than a detailed and balanced investigation. Our observations therefore suggest that students tend to approach tasks quite literally and tend to avoid considerations unless they are explicitly requested. For example, they include assumptions in a calculation only when instructed to do so. Students respond well to structured assignments probably because this is what they are most familiar with. In the work place less structured tasks are commonplace and students would benefit from more experience of them.

Concluding comments

It took 5 months to bring this case study to its present state of completion, with one of us working on it virtually full-time. Considerable time is involved in compiling all of the necessary information and in updating the tasks and format as a result of the first trial.

The production of a document that makes the study accessible to a range of tutors has also been a major consumer of time. However, we believe that our experience will enable us to extend the range of case studies relatively quickly. We draw attention to the following key features of our case study, which we believe will add significantly to their success.

- Minute keeping — a means to enhance the effectiveness of group work and the assessment thereof
- Help-mail — a method of improving tutorial support using e-mail
- Skills profiling — a way to identify skills level and development
- Oral presentations to experts and non-experts — aimed at promoting the importance of disseminating information to a wide audience
- Reflection — explicit requirement that students reflect on what and how they learned adds to learning-effectiveness.

Feedback from students has been positive.They welcome the chance to use their chemistry in a more applied context and appreciate the opportunity to develop both new and existing skills.We therefore conclude that this study (and others to be developed) will complement other available activities[e.g. 7-9].We welcome enquiries about availability.

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