This article was downloaded from https://rsc.li/30zaHTr

Exercises for chemists involving time management, judgement and initiative

PAPER

Simon T Belt*, Mike J Clarke and Lawrie E Phipps

Department of Environmental Sciences, University of Plymouth, Drake Circus, Plymouth, PL4 8AA
e-mail: sbelt@plymouth.ac.uk

Feedback from a range of learning opportunities frequently indicates that students feel they are given insufficient time, insufficient information, and insufficient guidance. In the light of this feedback, we have developed two exercises specifically designed to show students that real-life problems often involve coping with all three of these difficulties, and to provide opportunities to develop the skills needed to deal with the problems. These in-class exercises can be used either in isolation or as part of larger, integrated case study material. The material is also flexible in terms of level and student numbers and requires no special facilities. In order to enhance the perceived relevance of these activities, the underlying philosophy of the two exercises has been incorporated into a chemical context. Feedback on these exercises suggests that students can learn valuable lessons by completing them.

Introduction

Feedback between teachers and students takes many forms. Whatever the exact nature of this feedback, most of it is given by the teacher to the student in order to support or explain an assessment grade and to aid the learning process. It is also true that many teachers use a variety of teaching methods and/or develop new methods or styles in order to facilitate the student learning process further. But, how is the effectiveness of these methods evaluated? One way is to monitor changes in student performance in assessed work as a result of having introduced new methods or materials. This may be an appropriate measure of the effectiveness of some innovations and the best will show a positive response[1]. However, there are many reasons for supposing that this is a dangerous method to use for evaluating most changes in teaching[2]. An alternative to what Bodner describes as "the sports mentality approach to evaluation" is to obtain feedback from students and to use this to modify or update the material or mode of delivery if appropriate. This type of feedback can also be used amongst other things to verify that teaching standards are maintained from the student and tutor point of view, to provide evidence of good practice for external auditors and for supporting staff development[3,4]. Thus, the reasons for obtaining feedback are for judgement and improvement purposes. Over a number of years, we have obtained feedback from a large variety and number of students, usually at the end of lecture courses, tutorials, workshops and fieldwork. For each of these broadly defined teaching styles, feedback on assessed work has also been noted. Within this particular type of feedback, we have found there to be three extremely common and recurring themes as follows:

- insufficient time was allocated to complete the task;
- insufficient information was provided or available;
- insufficient guidance on how to tackle the task was given.

Of course, in some cases this feedback may be justified by poor teaching. However, more often, students may lack some key skills such as time management, information retrieval and the ability to think flexibly and creatively. One way to deal with this type of feedback would be to provide more instruction or help – a solution which could properly regarded as "colluding in a spoon feeding process"[5]. Since we believe that these three themes (limited time, information provided and guidance) represent real issues that students are likely to encounter outside of their courses (in the workplace), our approach has been to provide the opportunity to deal with them constructively within the chemistry curriculum. We have designed two exercises which are intended to illustrate these constraints in a positive, experiential way, and to provide an opportunity for addressing them. We have used these exercises in isolation and within more in-depth case study material that we have been developing[6]. They are suitable for use with any level of undergraduate study (though we prefer levels 2 and 3) and they can be used with class sizes of 5-35. No special facilities are required other than hard copies of the documentation and an OHP.

The first of these exercises is intended primarily to raise awareness that the three themes are often real constraints in solving problems (in the work place). The second exercise provides further opportunities to develop the skills needed to operate within these constraints.

Group Cohesion Exercise (GCE)

The first exercise is based on one of the exercises included in the module 'Personal and Professional Development for Scientists', developed by Maskill and Race[7]. In addition to being used in isolation as described here, the exercise acts as an effective 'ice-breaker' or method of introducing a larger programme of study involving group work (e.g. a case study). The utility of this type of 'chemical game' has been described elsewhere[8] and other recent and related examples are available[9]. In this instance, the group has a single objective which is to determine the precise nature of an environmental incident involving some herbicides. Each student is given one, or more information cards which between them provide sufficient clues to allow the correct conclusion to be reached.

Table 1 - Time Allocation for the Group Cohesion Exercise

TASK		Time (mins)
1.	Aims described	5
	Cards distributed	
2.	Groups share and discuss information	
	Arrive at conclusion	30-40
3.	Presentation of conclusion	5
4.	Discussion of solution	
	Reflection on the process	15-30

For this exercise we prepared 35 information cards some of which give key information, some provide supportive information, and some are irrelevant to the problem. In this way, the cards mimic the kind of information available to someone investigating a real incident of this type. We chose 35 cards because this number allows sufficient variety of information and means that the exercise can be used with a class of up to 35 students. The number of students in the class determines the number of cards each receives. The group need to decide on a mechanism for sharing all of the information, evaluate it by deciding which cards are key, supportive or irrelevant and agree on a conclusion based on this information. The conclusion is presented *via* a short (5 minute) talk which needs to include some justification. The model answer is then given by the tutor followed by a reflection session. Table 1 shows the time allocation which we have found appropriate.

The cards contain different types of information. One of the cards (shown in Figure 1) is a map of the area where the incident has occurred. Other cards describe characters involved (or not) in the incident, the timing of a series of events and extracts from letters and newspaper articles. Many of the cards relate to a chemical feature associated with the incident, so that students are made aware of the relevance of the exercise to chemists. These include information on chemical structure, spectroscopic data obtained from the chemicals and physico-chemical properties of the chemicals. Figure 2 shows six of the information cards by way of illustration. In practise, the map and cards (a) – (c) are key, (d) and (e) are supportive, while card (f) is a 'red-herring'. Since it is the group who need to arrive at these conclusions for themselves, they need to develop a strategy for disseminating and evaluating all of the information available within a limited timescale. This involves the group identifying and accepting the following features at an early stage:

- the time available is limited and not flexible;
- the information provided is all that is available and is sufficient to meet the objective;
- the initial instruction provides the only guidance for meeting the objective.

The group must not lose sight of these features though the precise method of arriving at the solution is not important.

An activity summary for the exercise is shown in Figure 3.

Commissioning A Monitoring Program (CAMP)

The second exercise described here is suitable for teams of 5 or 6, though several teams can work simultaneously and this can introduce an element of competition which adds extra impetus. We have worked successfully with class sizes of up to 35. We allow a total of 3 hours, which includes an

Figure 1 Map of the area involving the environmental incident

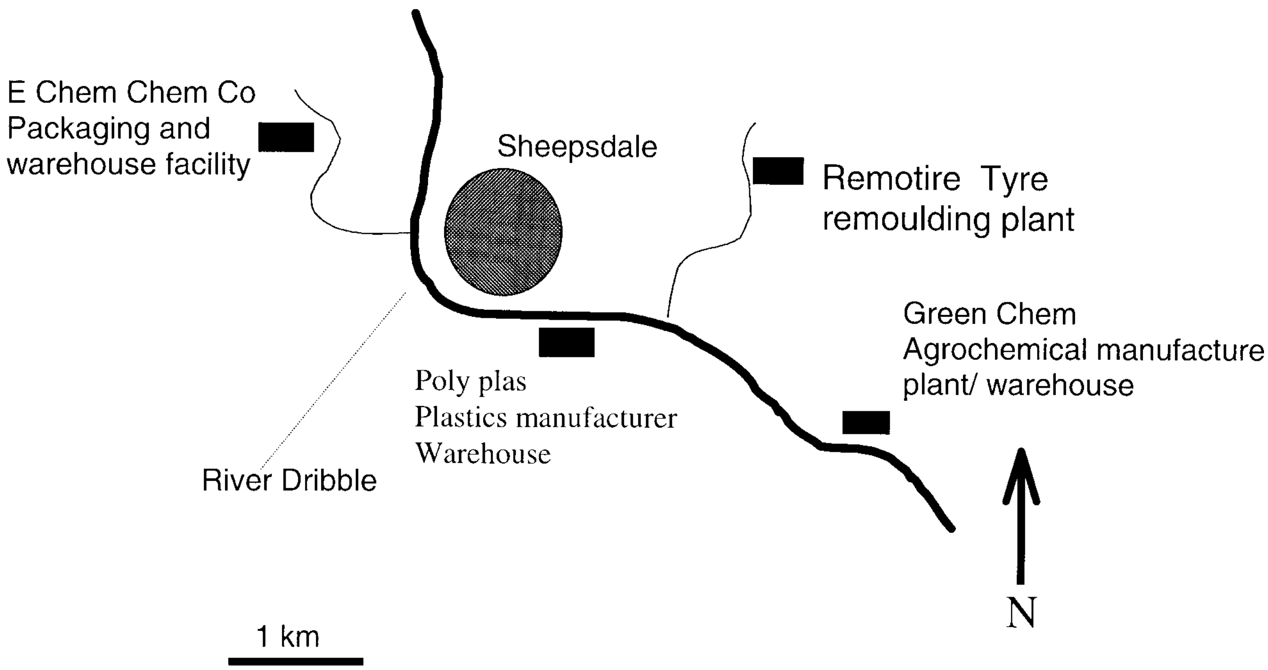
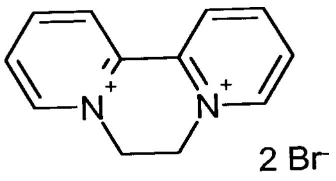


Figure 2 Examples of information cards

(a)

The chemical structure of Diquat Dibromide is:



- Water Solubility: 700,000 mg/L @ 20 °C
- Vapour Pressure: Negligible @ 20 °C
- Partition Coefficient: -4.6021
- Adsorption Coefficient: 1,000,000 (estimated)

(b)

You are Rick Niblet (date of birth 18/5/60). You wish you hadn't got quite so drunk on your birthday because, hung over and fuzzy headed, you forgot to switch off the heated shrink wrapping machine that you operate before you went home from work.

(c)

999 call list obtained from co-ordination centre at Sheepsdale May 19th 1987.

Incident	*Time*	*Service Required*
Suspected Heart Failure	7am	Ambulance
Lorry accident. Articulated lorry jack-knifed at Thrifty Bridge. Driver trapped in cab. Possible spinal injury. Lorry believed to be carrying hazardous materials	7.45am	Ambulance Fire Police
Drugs Overdose	8.30am	Ambulance
Fire at warehouse	8.30pm	Ambulance Fire Police
Baby Delivery	10.30pm	Ambulance
Baby Delivery	11.15pm	Ambulance

(d)

UV and IR analysis of an isolate from River Dribble from the EA sample point on May 20th 1987 showed a compound which had an aromatic moiety.

(e)

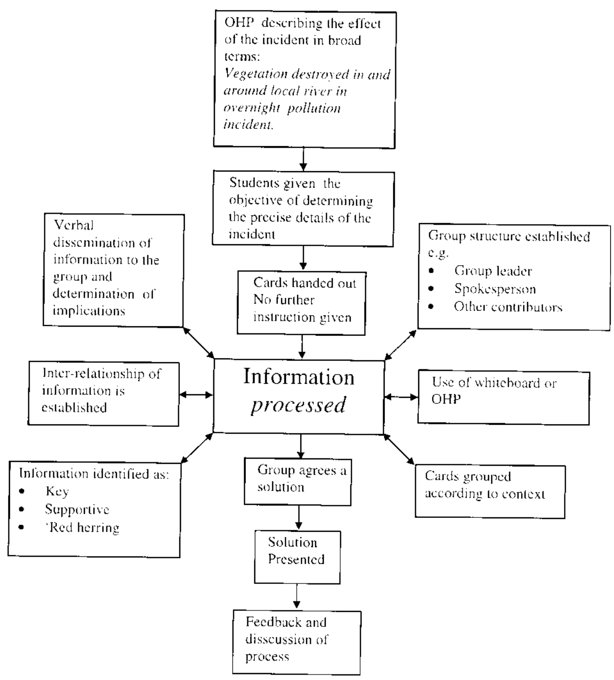
Relative Atomic Mass for selected elements

C	12
H	1
Mg	24
Ca	40
N	14
O	16
Cl	35.5
Br	80
I	127

(f)

You are Samantha Ridcully. You and your friend Audrey Grimsdale have been protesting without success about Nobby Giles' Dairy Farm. You both run a Vegan Restaurant in Sheepsdale.

Figure 3 Activity summary for GCE



introduction (5 min), arriving at a solution (120 – 150 min), and reflection (15 – 30 min).The exercise is the final stage in a series of five that constitute a case study dealing with the impact of a discharge of a herbicide (Diquat dibromide) and a surfactant (*p*-octylphenol) into a river system. Prior to working on this final task, the group will have completed the following activities:

- determined the precise nature of the incident (GCE described here);
- evaluated the likely impact of the herbicide and surfactant discharge into the river by consideration of the properties of the chemicals (literature review);
- determined the legal implications of the incident (researched Environmental Law);
- proposed a monitoring protocol for the two chemicals (literature review).

The general solution to the last of these activities (monitoring protocol) is that the two chemicals need to be monitored in two phases (sediment and water) over short and long term timescales, and using a range of analytical techniques. The quantitative aspects of the protocol (eg the exact number of sample measurements) is not important at this stage since this forms the basis for the final task, Commissioning A Monitoring Program (CAMP). This final exercise can be used as a stand alone activity, providing that the previous ones have been described in general terms in order to set the scene.

The group is given the role of working for the Environment Agency (EA) who need to complete a program of analysis of three chemicals. These are the herbicide and surfactant known to have been involved in the incident, together with a third chemical believed to be tributyl tin chloride (TBT), an anti-fouling agent. This is an industrial chemical commonly found in river systems and has a historical connection with the company.

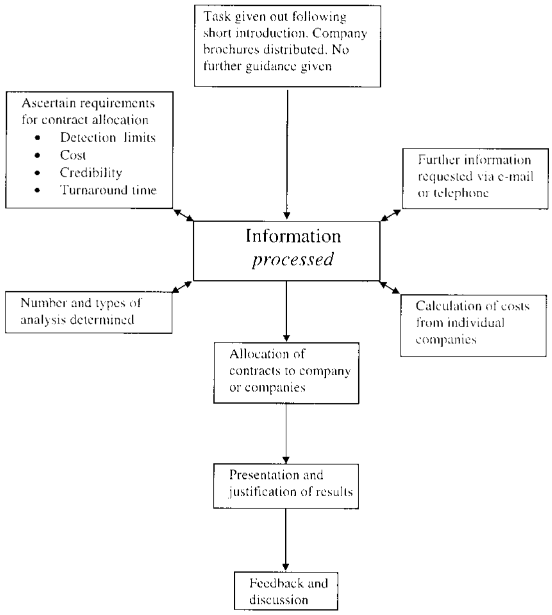
The group are given a single set of guidelines (see Appendix A) and with brochures from companies who carry out analytical work under contract[10].

The single objective for each group is to arrive at a quotation for the analysis that is at least competitive with that which can be offered by the EA. Part of the exercise involves relatively straightforward numerical analysis. However, it is also important to consider factors such as:

- the accreditation status of the companies;
- the detection limits of the analytical procedures;
- the number and type of samples to be analysed;
- the turn around time.

Some of the information needed is provided explicitly in the guidelines (Appendix A) or in the company brochures. However, the guidelines and brochures have been designed to ensure that students are operating within constraints of *limited information* and *limited guidance*. All the documents need to be read and discussed critically. Appendix B gives amplified examples of the factors which students need to consider, and some comments on how the information they have been given maps onto the problem. This illustrates how the process of arriving at a conclusion involves time management and other skills such as those described by Overton[11] including 'critical reading', 'constructing and understanding argument', and 'making judgements'.

Figure 4 Activity summary for CAMP



An activity summary for this exercise is shown in Figure 4.

Results

The results achieved by students have varied substantially depending on the aptitude and attitude of the participants.

GCE

In almost all cases, participants have been able to reach the required conclusion in the allotted time. The most successful groups recognise at an early stage the need for a central collating mechanism. This may take the form of one person collating a summary of all the information available using a whiteboard so that the entire group can observe the connectivity of the clues and the conclusion as it emerges. Another common method of performing this task has been for the clue cards to be grouped together according to their type (character, time of event, chemical description etc) and graded as to their possible significance. Groups who fail to instigate a strategy at an early stage have usually required some tutor assistance before arriving at a reasonable conclusion. In a large class it is usually possible for the quiet or retiring student to hide behind the active or vociferous ones. However, in this exercise, the key cards are as likely to be held by the retiring student as the assertive one. Thus, all the students must participate, at least to a limited extent. A key issue for the reflection stage is to encourage all the students to consider the effectiveness of their own contributions to the process of sharing and evaluating the available information.

Commissioning A Monitoring Program (CAMP)

This exercise requires the application of a greater variety of skills to achieve a successful resolution of the problem. The range and level of skills held by the group members has therefore had a marked impact on general performance and quality of the results. Effective communication between group members is again key to a successful resolution of the task. Students who have completed the GCE will have learnt the need (and discussed some strategies) for effective time management and this is apparent from their reflection on this exercise. In the context of the CAMP exercise, the students generally recognise that delegation of tasks to individuals is essential to obtain a result within the given time constraints. This has been a common theme of feedback and reflection showing that this exercise is particularly successful in illustrating the importance of this issue. Groups members with good mathematical ability have found the numerical aspects of the exercises relatively straightforward. Those with a weaker mathematical background have sometimes struggled, and failed to reach a satisfactory conclusion. Most participants deal reasonably well with the other factors outlined earlier and in Appendix B, though it is not uncommon for one or more to be overlooked at first and some prompting from tutors may be needed. We have found it is important to emphasise that the exercise reflects real life in that students may have to use their initiative to seek additional information (which may or may not be available). To facilitate this, the tutor role-plays as a contact point with companies (if necessary using e-mail or telephone). Once students appreciate this role-playing aspect of the exercise they rapidly take advantage of it.

Undoubtedly, one of the most challenging issues of the exercise has been the oral presentation of findings. Determining a satisfactory solution to the task is one thing, but shifting gear into having to present it is another. Students find it difficult to organise themselves to give the presentation on time, since determination of the solution is perceived as being the most important feature; they also have difficulties in selecting the most appropriate information to make a convincing conclusion. Indeed, the students themselves often discuss in the reflection session that the quality of their presentation does not do justice to their well worked solution. This can be a cause of some frustration, but usefully illustrates the importance of being able to solve a problem and present the results within a limited timescale – as many will have to do in their working lives.

Chemistry in Context

For both exercises, the chemical context seems to be important in making the exercises relevant to chemists. It can also provide a distraction from the main aims. This is not necessarily a disadvantage; it can provide a 'safety net' for groups which might otherwise fragment when having difficulty in evaluating and using the available information. Amongst other things, groups have debated at length 'the substitution chemistry of heteroaromatic compounds (Diquat dibromide)' or 'the use of toxic ethyl bromide in the synthesis of herbicides' even though this information is irrelevant to the exercise. This gives them some feeling of security until the tutor is able to bring them back to the key issues. This prevents the students losing interest and motivation, and also raises as a valuable point for reflection their willingness to be sidetracked into unnecessary chemical detail.

Reflection

Reflection is a key part of the learning process[12]; it helps to identify a need for key skills, a mapping procedure by which skills and actions can be correlated, and a means of monitoring progression or development. Therefore, after each of the two exercises, there is a tutor-led discussion session that encourages the students to reflect on their performances both as individuals and as a group. The group reflection takes the form of a debate and involves the group commenting on their performance or level of achievement as measured against their own criteria, and also, an identification of how the specifics of the group work activities can be categorised in terms of group skills development (eg the need for an effective interchange of *all* information before it can be evaluated (GCE) or prioritising and division of tasks within a restricted timescale (CAMP)). A strategy of how the group may perform better on another occasion is often agreed upon. Individual reflection is then carried out by each student via a *pro forma* and this can be discussed further with the tutor if desired. During this part of the reflection process, students are encouraged to think about what they did to contribute to the group, identify a role and consider how effective their contribution was. They are also asked to look at areas for personal improvement and consider whether their style of contribution would always be appropriate or effective over a range of different types of activity. For example (GCE), some students may identify an effective contribution as one where they simply pass their card(s) to a leader without need for any further input. This however, should be seen as being a strategy of limited value particularly when a number of tasks need to be achieved in a restricted timescale (e.g. CAMP).

Considering Feedback

We have used these exercises over the last two years with postgraduate and level 2 and 3 Chemistry and Environmental Science students in Plymouth and academics at project IMPROVE workshops. During these trials, we were satisfied with the operational aspects of the exercises, but we were not so pleased with student feedback. Students welcomed the opportunity to perform group problem solving activities, but when the specifics of the group work were addressed, there were frequent complaints that there was 'insufficient time' or 'insufficient guidance'; the exact issues that we had set out to address! Interestingly, in describing the results of a recent graduate survey, Duckett *et al*[13] concluded that while chemistry students generally feel that they have received adequate provision of group work in their courses at a broad level of definition, when the utility of this experience is examined more closely (eg in motivating others, understanding the perspective of others and contributing effectively to discussions) it is often found lacking. In considering the negative feedback received from the initial trials, we were aware of becoming involved in a 'Catch 22' type scenario[14] whereby too little guidance would fail to encourage the students to think about how they would work within constraints (although the constraints themselves may be identified), while too much guidance might defeat the objective. In conclusion, we decided to re-structure the aims of these two exercises in order to achieve two different but related outcomes. The first of these involves a recognition of specific constraints and a consideration of how to work within these (GCE), while the second gives the students an opportunity to develop these methods and reflect further (CAMP). In more recent feedback, students describe 'the need to actively involve all group members', 'the need to consider the views of others' and 'the importance of critically considering information available and requirements' to be key features learnt. They are also enthused that their own feedback has been used to improve their learning experiences.Feedback from academics (to date only the GCE) has concentrated on how valuable the exercise could be for their students rather than themselves! They have also anticipated that the exercise must have taken a considerable time to put together. While the authors agree with this, it may be worth noting that the key to this process was having a template structure[7] and a final solution to work towards. Thus, the creation of related exercises may be readily achievable.

Conclusion

Both exercises provide an opportunity for students to perform activities within a series of constraints (limited guidance etc). The first of these (GCE) is particularly effective at raising an *awareness* of the importance of key skills and identifying strategies for working within these constraints while the CAMP exercise provides an opportunity to *apply* these strategies and develop them further.

Groups of students tend to tackle the two exercises in a number of different ways probably due to the 'no guidance' strategy employed by the tutor.This in itself is not important. What is considered to be important is the post exercise reflection both within the group and between the groups. This way, students can learn about their thinking skills both from themselves and from each other.

Students and academics have enjoyed taking part in these exercises,and students in particular welcome the opportunity to develop their transferable skills within a chemical context. However, student progression can be a slow process. It is unlikely that students become overnight experts in disciplines such as time management and critical reading as a result of taking part in these exercises, but we have found them to be effective methods for raising awareness of these essential skills and providing an opportunity to explore methods for working within various realistic constraints. The lessons that students learn *via* these exercises and the subsequent discussions can then be applied within the wider context of their courses. The opportunity to 'do' and 'reflect' at appropriate times is considered to be key in enhancing the effectiveness of these two exercises.

Acknowledgements

We would like to thank Nick Craig (Zeneca Environmental) for initial discussions and information relating to the content of the case study, Sally Stansfield (Alcontrol, plc) for advising us on technical brochures and costings and to project IMPROVE for funding to STB. We would also like to acknowledge Stage 2,3 and postgraduate students at Plymouth together with a number of academics at project IMPROVE workshops for participating in these exercises and providing valuable feedback on whose feedback these exercises have been based.

References

1. Lowry R B 1999 Electronic Presentation of Lectures – Effect upon Student Performance *UChemEd* **3**, 18-21.
2. Bodner G MacIsaac D White S 1999 Action Research: overcoming the sports mentality approach to assessment/ evaulation. *UChemEd*, **3**, 31-36.
3. O'Neil M and Pennington G 1992 Evaluating teaching and courses from an active learning perspective from *Effective Learning and Teaching in Higher Education*,No.12, University of Sheffield
4. Bonetti S 1994 On the use of student questionnaires *Higher Education Review* **26** 57-64
5. Coldstream P 1997 Chemistry education for a changing world *UChemEd* **1** 15-18
6. Belt S T and Phipps L E 1998 Using Case Studies to Develop Key Skills in Chemists:A Preliminary Account *UChemEd* **2** 16-20.
7. Maskill R and Race I 1997 Personal and professional development for Scientists, Proceedings,Variety in Chemistry Teaching (ed. Garratt J and Overton T), (Royal Society of Chemistry)
8. Wallace R and Murray B 1998 Chemical games to improve communication skills *UChemEd* **2** 63
9. Bailey P 1997 Coaxing Chemists to Communicate *UChemEd* **1** 31-36
10. Copies of the brochures are available from the authors on request.
11. Overton T 1998 Creating Critical Chemists *UChemEd* **1** 28-30
12. Tomlinson J 1998 Reflecting on Learning, *UChemEd*, **2**, 35 (and subsequent correspondence)
13. Duckett S B Garratt J and Lowe N D 1999 Key Skills:What Do Chemistry Graduate Think? *UChemEd* **3** 1-7
14. Heller J 1962 Catch-22 (Jonathan Cape, London)

Appendix A: Student guidelines for the exercise

'Commissioning A Monitoring Program'

May 19th 1987 **2.00** p.m.

You are working for the Environment Agency and have been charged with the task of obtaining monitoring analysis for three compounds, which are thought to be present in the River Dribble following the fire at the warehouse. These are Diquat dibromide, *p*-octylphenol and tributyl tin chloride.

Monitoring should take place initially on a daily basis from the 20th of May 1987 for the first fourteen days of the program followed by weekly monitoring for the subsequent six weeks. Following the initial eight-week monitoring period, a monthly check is to be made for an indefinite period until such time as the levels have dropped below the maximum allowable concentration. This monthly analysis should only include tributyl tin chloride and *p*-octylphenol but analysis will continue on both water and sediment sample types. It has been calculated that the cost to the EA to perform this analysis 'in house' would be in the region of £300,000. It is suspected that this may be more economically achieved by contracting the work out to private companies. You are therefore supplied with brochures from four companies from which to make your choice.

You may employ any company or combination of companies for any service to obtain the lowest cost data within the constraints within which you are working.

You will be required to obtain analysis for 12 water samples and 9 sediment samples for each of three sampling sites, though sediment samples are not required for Diquat dibromide analysis. Turn-around time for the analysis should be within seven days for the Diquat dibromide samples and within twenty-eight days for the tributyl tin chloride and *p*-octylphenol samples.

The budget must include costings for collection of samples and transport. This may be performed by the EA or as part of a package, which may be provided by any of the nominated companies. Detection limits required are as follows:

	Sediment	Water
Diquat dibromide		0.1 μg dm^{-3}
p-octylphenol	1.4 ng g^{-1}	1.0 μg dm^{-3}
tributyl tin chloride	10.0 ppb	1.0 ppb

Costing of sample collection per collection date

Total sampling time per visit	(hours)	8.00
Cost per hour		£15.00

All companies must be either UKAAS/NAMAS, GMP or GLP accredited. One of the nominated companies is German based. The current exchange rate is DM/£, 2.75. Each conversion attracts a 2% commission by the exchanging bank.

You may only budget up to the end of 1987. You have until 5.00 p.m. to make your choice(s).

When you have arrived at a budget you will be required to give a 10 minute presentation justifying **all** your decisions.

Appendix B: Examples of questions addressed in the CAMP exercise.

How many samples are required of each type? Is it necessary to consider this or is it sufficient to determine a unit cost?

The calculation of a unit cost may be seen as a means of saving time that could be better used on other activities. In fact, there are discounts from some companies for larger numbers of samples and so the exact number is important. Further, since the outcome of the costings analysis and therefore the entire exercise depends directly on the number of samples, this determination needs to be checked carefully.

Are all of the costs fixed?

Apart from discounted rates applied to bulk quantities of samples, the German company quotes their costings in DM. Although the exchange rate is given, this undergoes a change half way through the allotted time. The impact of this depends on the progress of the group at this stage but it can require them to reconsider their options dramatically. Thus, working under shifting timescales is illustrated.

Does the absence of explicitly named chemicals in some of the brochures mean that these cannot be analysed?

No. In most cases, chemicals are referred to by a general classification, so each one needs to be mapped onto a compound type. Thus, Diquat dibromide can be classified as a bypyridylium herbicide, *p*-octylphenol as a surfactant and tributyl tin chloride as an organo tin compound. This requires that the students do not lose sight of the underlying chemistry involved.

Are any or all of the companies capable of meeting the detection limit and turnaround time requirements? Is all of the information available?

None of the companies offer detection limit information and only one indicates the analysis time. However, all of the brochures invite potential customers to request further information if needed. When the group does this for the first time, all of this additional information for the 4 companies is provided as a single datasheet which reveals that in a number of instances, the detection limits are not achievable. The need to interconvert units and to check these is key at this stage. One of the companies does not provide any brochure costings of individual chemicals but offers an 'instant' e-mail quotation. If the request form is submitted correctly (ie correct number and type of samples), the group is given an immediate quotation. If the submission form contains errors, there is a delay (since the revised costings would need to be calculated by the tutor) which may alert the group to there being an error.

Have all of the companies received accreditation (UKAS/NAMAS, GMP or GLP)?

This is part of the fundamental guidelines. One of the companies has received no accreditation and can therefore be discounted before any costings are considered. This would otherwise be the cheapest company, so this guideline needs to be considered carefully. Additionally, the quality of this company's literature presentation is particularly poor and suggests that they may not be sufficiently competent or experienced to deliver the services they offer. Hopefully, this fact should be identified and highlighted by participants.