Developing critical and communication skills in undergraduates through chemistry

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A group-based Critical Skills Workshop (CSW) designed to encourage students to (a) think critically about scientific questions and (b) write and present chemistry to an audience according to challenging rules has been run at Leeds University School of Chemistry for two years. Described here is the workshop framework along with practical details of resource, facilities and a breakdown of time and assessment commitments for the CSW at Leeds.

Introduction

Arguably[1], three of the most important characteristics of a university graduate are an ability to:

- *Acquire* information;
- *Analyse* information;
- *Communicate* information.

As teachers of chemistry we all appreciate the need to provide our students with chemical information through lectures, tutorials, laboratory classes, etc. This is confirmed by the conclusion of the Royal Society of Chemistry that

"*the main emphasis has traditionally been on the development and application of a knowledge base in chemistry.*"[2]

However, as this report acknowledges, it is equally important for students to gain experience at both *analysing* and *communicating* information as part of the curriculum, especially at the crucial First Year undergraduate level. Most undergraduate courses in chemistry provide experience in analysis through problems classes, workshops, course-work problems and self-study packages. Communication skills however, are too often perceived by students as being of secondary importance because they form a part of some other activity - written course-work, laboratory reports and possibly an oral presentation as part of a laboratory or literature project. A notable exception to this generalisation[3] suffers from the disadvantage that students do not meet the module on communication skills until their penultimate year.

Our approach in Leeds is to blend two teaching tools, Critical Thinking (CT) Exercises[4] and the One-Minute Lecture (OML)[5], into a team-based workshop taken by all Level 1 chemistry undergraduates as part of their 30-credit Practical Chemistry Module which runs across Semesters 1 and 2. Outlined here are the workshop framework, resources, facilities and a breakdown of time and assessment commitments for the CSW at Leeds which we hope will be helpful in transportation of the package to other departments. Workshop guides and briefing notes of the Leeds model are available as supplementary material[6].

Educational and learning objectives

There is more to teaching than merely providing information. It is equally important to influence which pieces of information students retain and also how students make sense of that information in the light of their background knowledge and experience[7, 8]. Indeed, recent studies by Johnstone and co-workers suggest that students perform better in the laboratory or examination room when they are able to *focus on the key facts and filter out those that are less important to the job at hand*[9, 10, 11].

They conclude that a students' ability to do this is influenced by three factors:

- the size of the information content;
- how well the student has already developed the concepts needed to handle a particular problem;
- the difficulty perceived by the student.

The key point is that learning is facilitated if the perceived difficulty is low. This can only be achieved by keeping the information content low and/or ensuring that the concepts needed are thoroughly understood. Our Critical Skills Workshop (CSW) at Leeds is designed to give students experience of five key skills whilst working within a framework of low perceived difficulty. The key skills are:

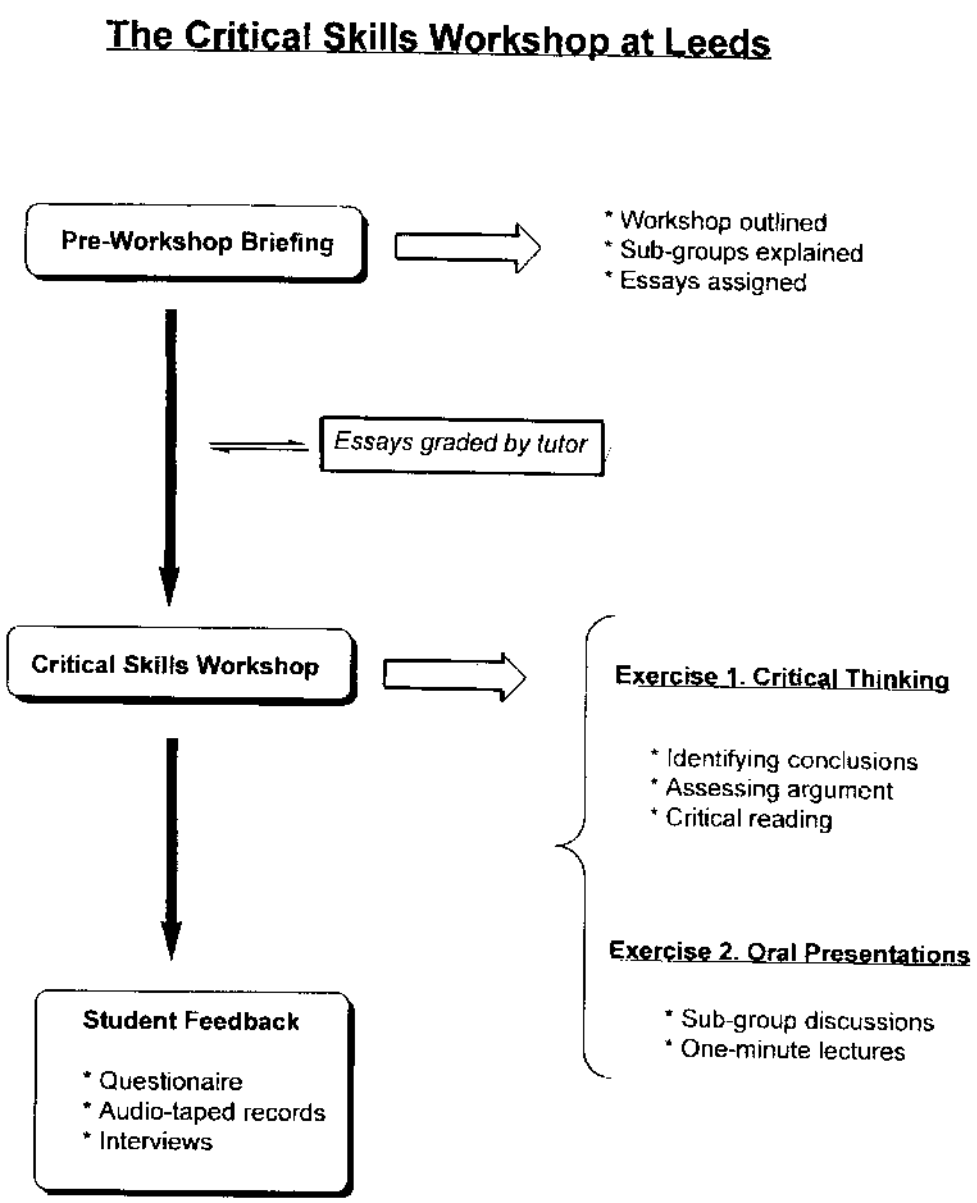
- Adopting a *critical* approach to solving problems.
- *Selecting* information appropriate to a set task.
- *Communicating* arguments, both written and oral, in a concise manner.
- Working within tight *time constraints*.
- Working as part of a *team*.

The Critical Skills Workshop in Leeds

Resources and facilities

The CSW forms part of the Level 1 Practical Skills Module *Chem 1400*. This is a 225 hr, 30 credit module (10 credits equates to 75 hrs study time) which runs across both Semesters 1 (Oct-Jan) and 2 (Feb-June). It comprises three

Figure 1: A critical skills workshop at Leeds



laboratory sessions (organic, inorganic and physical), each of 8 weeks duration, in addition to the Critical Skills Workshop, a course in remedial mathematics and a two-week intensive course in Basic Computing. For the CSW the combined Level 1 Chemistry cohort is divided into three groups each of 35-40 students. Each group takes the CSW as a once-only, two-hour event as part of a rotation which also includes the four 3 hour sessions on Computing Skills. In addition to the workshop itself (ca. 2 hr), students attend a 30 minute pre-workshop briefing and write a two-page essay (expected to occupy 6-7 hours of their time) which is graded (*vide infra*). The CSW is run by a single tutor. The organisation is summarised in figure 1 and a more detailed list of resources and requirements for CSW as run at Leeds is provided in table 1.

Pre-workshop briefing

Seven days prior to each workshop, a 30-minute pre-meeting is held at which the 35-40 students are further divided alphabetically into 6 or 7 sub-groups or teams. Each team is presented with an essay title chosen to reflect a broad yet topical field of science (table 2). Each student is instructed to prepare individually, an essay of no more that four sides A4 paper. They are told that this should take them 6-7 hours and that 24 hrs prior to the workshop it must be submitted for grading by the tutor[6]. The purpose of the pre-briefing is to

- introduce group members;
- supply essay titles;
- brief the group on the organisation of the workshop to be held in seven days time.

Table 1

Staff requirements	One tutor is sufficient
Student numbers	3 x 35 (Level 1 intake in total)
Time-load (students)	(i) 30 minutes, pre-workshop briefing (ii) ca. 6–7 hrs essay preparation (iii) 2 hr workshop
Time-load (staff)	(i) Preparation (ca. 3 h) (ii) Grading essays (ca. 48 h) (iii) Workshop (2 h) (iv) Feedback/analysis (open)
Accommodation	Room equipped with overhead projector and tables/chairs for 6–7 groups of 6–7 students each.
Materials	(i) Overhead projector (ii) Transparencies (x 100) (iii) Pens (x 35–40) (iv) Workshop guide
Assessment and monitoring	(i) Graded essay (formal) (ii) Student questionnaire (informal)

Table 2: Essay Titles Selected for Critical Skills Workshop[a]

Colour
The Structure of the Atom
Radioactivity
Water
The Greenhouse Effect
What is a Flame?
Enzymes

[a]One, 2 page A4 essay per group, no texts specified, content entirely at the discretion of the student, students have six-working days to produce the completed essay for a nominal 6-7 hr exercise. We chose titles to be topical, broad-based and not associated with particular teaching modules but more module-specific titles would be equally appropriate depending upon the learning objectives.

Although the students are told that their essays will form an integral part of the CSW, they are not told how; the main reasons are to guard against fore-knowledge and preparation on the part of the student (*vide infra*).

Running the workshop

Once assembled for the workshop proper, the graded essays are returned and the students are provided with a copy of the associated CSW workbook[6]. The objectives and organisation of the workshop are explained in greater detail. The two Exercises, *Critical Thinking* and *Oral Presentation* each take about half of the allotted 2 hours of the Workshop, and students work in their teams.

Critical thinking

Garratt, Overton, Threlfall and colleagues[11] have developed exercises designed to probe the different ways in which scientists think about scientific problems. Three types of exercises have been described[4] each designed to encourage students to consider a different aspect of scientists' thought processes; (i) identifying conclusions, (ii) assessing arguments and (iii) critical reading. We select a set of two or three problems of each type, allocate ten minutes for the teams to agree on their answers to each set. This is followed by a ten minute, tutor-lead discussion on solutions to each of three types of problem which concludes with a list of conclusions as 'take-home messages'[6].

Oral presentation

Following a five minute break at the end of the first exercise, the students come together again in their teams for the second exercise, being unaware of the precise nature of the task ahead.

The task is for each team to prepare and deliver a one minute lecture on their essay topic. Each team is presented with a single overhead transparency and three colour pens. They are instructed to prepare and deliver a *lecture* on their essay topic according to the following rules:

- the lecture must be presented on the single overhead transparency;
- each team has ten minutes to prepare the lecture;
- teams can decide how they organise their lecture and who is involved in the presentation;
- teams are instructed to pitch their lecture for an audience of scientifically literate non-specialists (ie themselves!);
- the objective of the lecture is to convince the audience of the importance of their essay topic;
- each lecture must last no longer than one minute! (timed by the tutor).

The topic of the essay is so broad that each student in the team is likely to have approached it from a different angle. One of the problems they face is therefore the selection of material from what is available. Given the short time available to write their lectures, students find themselves engaged in some quite frantic yet exciting activity in deciding amongst themselves who is to do the writing, who the presenting, what parts of their essays to include and which to leave out. All teams quickly come to realise that with one overhead and sixty seconds available, they can only present the key points and most choose to do so in a highly pictorial, eye-catching manner. They also recognise, especially after the event, that sixty seconds is a very short time and that they have to think very carefully what material is relevant and what is less so.

Assessment

Although the essays are graded, the workshop has not been assessed to date. However, we are planning to incorporate CSW within a broader Level 1 skills-development programme wherein further guidance will be giving in writing and presentation techniques prior to the sessions. We envisage that the essays will be tutor-assessed in the usual way whilst allowing for the possibility of peer-assessment of the group presentation. These and further developments will form the basis of future publications.

Effectiveness of the Critical Thinking Workshop. A research study

At the end of the workshop, each student is asked to complete a questionnaire dealing with procedural aspects[12]. These are collected, collated and used to fine-tune the sessions (eg alter timing of exercises, number and type of Critical Thinking problems etc...). In addition, as part of a wider study into students' experiences of learning about the actual practices of science[13], one of us (JR) has initiated an investigation of students' views of CSW activities. This involves direct observation of three CSW sessions, audio taping of selected student group discussions, interviews with selected students and the tutor after each CSW session. This study is designed to identify key elements of critical thinking which are important to the practice of chemistry, to consider how students can develop their ability to think critically, to consider the impact of CSW on student learning elsewhere in the curriculum and to identify those aspects of CSW which are most effective in developing students' abilities to interpret chemical information critically.

Interviews with students addressed their general attitudes towards the session, and how they felt the CSW compared with other curriculum activities. The results of these discussions are currently being analysed in detail and will be described in more detail in future publications.

However the general response from the students has been very positive, and they find the CSW both thought provoking and stimulating.

The audio-recordings of the group discussions revealed that the content and depth of discussion in different groups was very variable. This emphasises the importance of the tutor-led discussions in which the tutor takes responsibility for stimulating all groups to contribute and ensuring that all groups understand the key lessons.

Preliminary analysis of the interviews shows that the students recognise this important role of the tutor. Many students also emphasised the value of engaging in group discussion about chemistry as is illustrated by the following comment:

"it seemed to help me talk in a group more than I usually do. The questions were really good for that I thought. If I could see what the answer was and someone said it was something else, I was straight in there saying 'I think it is this', whereas sometimes I'd stay back a bit and not talk."

A particularly welcome finding was that most student interviewed felt that the insights gained during the sessio would be of use to them elsewhere in the undergraduat chemistry curriculum.

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