Key Skills: What Do Chemistry Graduates Think?

PAPER

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We report the results of a survey in which we have tried to identify which key skills are most needed by recently employed chemistry graduates, and how well they feel they are being prepared for using these skills by their chemistry courses. Across the range of job-specific skills covered in the survey, the results show a general correlation between the extent of relevant course content and the importance of the skill to typical graduate employees. However, the results also support employer opinion that there are areas in which graduates could acquire more job-specific skills, and some suggestions are offered on approaches to exploiting more effectively the opportunities for skills development within chemistry courses.

Introduction

Typical surveys of the proficiency of graduates in the workplace reflect the opinions of the *employers* of graduates[1,2]. They conclude that graduates could be better prepared for the world of work by their university education. This concern is being addressed by a number of initiatives which set out to teach chemistry in a way which delivers chemical knowledge whilst encouraging students to develop skills. Clearly, these initiatives will be most effective if they address the skills which are most needed.

Employers naturally have high expectations of the graduates they employ. Consequently, regardless of the absolute quality of recruits, they will always be able to identify areas where their employees could improve: the expectations of employers may be somewhat unrealistic. More relevant information about the skills which graduate chemists need and their opportunities to develop these skills may be obtained by surveying recent graduates directly. The DfEE "Alumni" project was set up for this reason. Reports on eleven completed projects (of which this work comprises part of one) are available[3]. One of these includes a survey of chemistry graduates[4]. Another recent survey also relates specifically to chemistry graduates[5]. However, this was limited to those working in the chemical and related industries, and the questions were not designed to allow respondents to compare their need for skills with the opportunity to develop them during their university courses. We perceived the benefits of such a survey as follows:

- Graduate employee opinion might temper unrealistic employer expectations.
- The familiarity of recent graduates with the content and structure of university courses means that they will make a better connection between what they now do and what they did at university.
- This is likely to yield more realistic suggestions as to how courses might be improved in order to facilitate progression into a wide range of jobs.
- Initiating such a survey may help establish permanent mechanisms for using feedback from recent graduates to influence the structure and content of degree courses and to develop closer links between industry and academia in teaching as well as in research.

A brief abstract of this work has been published previously[6].

Methodology

The strategy of this study and the design of the questionnaire were discussed and agreed by a consortium of academics and industrial representatives already convened to advise on a previously reported project[7]. The objectives of the study were defined as:

- to obtain information about the skills which graduate chemists find that they most need in order to make an effective contribution to their work during their first years of employment;
- to establish whether graduates believe that their first degree courses provide them with the opportunity to develop these skills.

We decided to send the questionnaire to all students graduating in a particular year from selected universities: Edinburgh, Hull, Plymouth, Sheffield Hallam, UEA, Warwick and York. Questionnaires were distributed during the summer of 1998 with the help of colleagues in the universities concerned. They were sent to all those graduating in 1995 with a BSc, MSc or PhD, where chemistry had been the major component of their *first degree*. The year 1995 was chosen because it would include a proportion of respondents still engaged in studying for a higher degree as well as those who had taken up employment on graduating either with a BSc or with a higher degree.

We decided to base the questionnaire on a set of specific action statements: a typical action statement is "contribute effectively to discussions". This approach was intended to remove any ambiguities resulting from the various interpretations which it might be possible to put on more general questions particularly where these included ill-defined terminology (e.g. "did your course develop communication skills?", "how important is problem solving in your job?"). In order to meet the two objectives of the study, two responses to each action statement were required - one referring to the importance of the action in the work environment and the other referring to the opportunity to develop the ability during the undergraduate course.

Before preparing the questionnaire, we conducted structured interviews with nine students who had returned to York to complete their courses after a year spent working in industrial placements. This gave us an overview of the most appropriate action statements to use in the survey. On this basis, we prepared a draft questionnaire which was trialled by a specially convened group of seven chemistry graduates currently working in the chemical industry.The final version took account of their comments and also of the consortium of industrial representatives and academics referred to above.

A total of 22 specific action statements were included; these are listed in full in Table 1.The wording for the two questions relating to each action statement was "In your job, how important is it for you to be able to..." and "How did your degree course prepare you to...". Respondents used a numerical scale of 0(Not at all)-3(Very (well)). Space was provided after each action statement to allow respondents to give further information on the nature of any coursework they considered relevant.Thus,they could tick boxes to distinguish between specific ("Explicit training") and general ("Chance to practise") preparation and give examples.

The questionnaire[8] was introduced by an explanation of our aims in collecting the information, with clarification of the three response fields and the difference between "Explicit training" and "Chance to practise". Respondents were specifically asked to address their **first degree** when making their responses. They were also asked to identify the university from which they had graduated and provide information about their current employment. The questionnaire concluded with a number of open-answer sections, one in particular being discussed below:

"Please indicate any other skills, relevant to a degree course, which are important in your job or which it would be beneficial for you to have."

Results

580 questionnaires were sent by post with a FREEPOST reply envelope. 125 replies were received (a response rate of 21.6%); 104 (83%) had obtained BSc in 1995, 19 (15%) PhD, and 2 (2%) MSc. All respondents completed some, or all, of the open-answer sections with 52 (42%) responding in all sections. Figure 1 provides a breakdown of the respondents by occupation. The mean values of the numerical responses to each of the two questions, for all 22 actions, are listed in Table 1. The combined response of all 125 respondents is shown in bold; also shown are values for the respondents by type of occupation. The subsequent discussion will refer only briefly to the differences in response between the different occupations, partly because of the lack of clear conclusions (due not least to the different numbers replying in each category) but principally because our interest is in chemistry degrees as preparation for careers in general rather than for any particular career. Graduate employee responses to the open-answer question quoted above are summarised in Table 2.Table 3 contains complementary information sourced from the Chemical Industries Association[2] making for some interesting comparisons of employer and employee perceptions of those areas in which graduates could most usefully receive better preparation.

Figure 1: Number of survey respondents by occupation

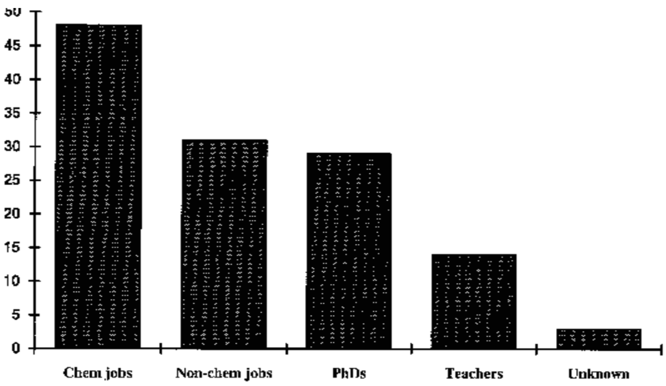
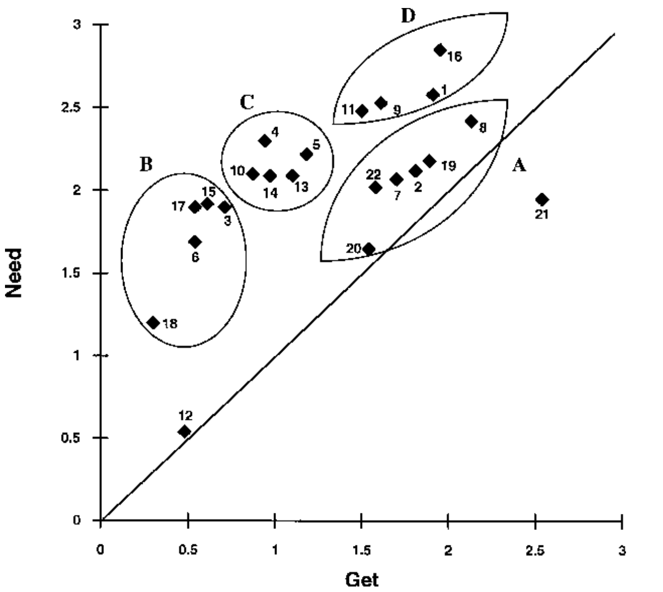


Figure 2: Representing the correlation between the importance of actions **1-22** in jobs and their coverage in chemistry degrees



Discussion

Overview

The first set of figures in Table 1 provides a measure (on a scale of 0-3) of the extent to which the ability to perform each action is required across the full spectrum of jobs ("Need") and the second set provides a similar measure of the extent to which preparation for performing these actions is provided during a chemistry degree ("get"). By far the most needed ability is to "manage your time between a number of overlapping tasks" (**16**), perhaps not surprisingly, followed by "update your knowledge of skills on your own initiative" (**1**). This appears to vindicate Dearing's decision to identify "learning how to learn" as a distinct key skill[9]. At the other

Table 1: Combined response to 'Need' and 'Get' for actions **1-22** for all respondents, and for respondents by occupation type.

Action Statement	*'NEED'* *In your job, how important is it for you to be able to...* (0-3)					*'GET'* *How did your degree course prepare you to...* (0-3)				
	All	Chem.	Non-chem	Ph.D.s	Teacher	*All*	Chem.	Non-chem	Ph.D.s	Teacher
1. ...update your knowledge and skills on your own initiative?	*2.58*	2.40	2.52	2.93	2.50	*1.91*	1.77	2.10	1.90	2.00
2. ...work in small teams to perform a task?	*2.12*	2.34	2.45	1.48	2.07	*1.81*	1.83	1.90	1.69	1.79
3. ...motivate others to contribute to a particular task?	*1.90*	1.88	2.06	1.31	2.71	*0.71*	0.73	0.74	0.62	0.93
4. ...understand the perspective of others?	*2.30*	2.23	2.48	1.90	2.93	*0.94*	1.13	0.90	0.71	0.93
5. ...appraise your own performance?	*2.22*	2.15	1.97	2.45	2.50	*1.18*	1.33	0.94	1.17	1.14
6. ...appraise the performance of others?	*1.69*	1.57	1.61	1.31	2.79	*0.54*	0.55	0.39	0.59	0.79
7. ...give presentations to colleagues on areas which you have evaluated?	*2.07*	1.98	1.61	2.83	1.71	*1.70*	1.73	1.90	1.48	1.57
8. ...write concise reports to summarise material for colleagues?	*2.42*	2.50	2.26	2.55	2.07	*2.13*	2.19	2.35	1.86	1.93
9. ...contribute effectively to discussions?	*2.53*	2.46	2.45	2.62	2.71	*1.61*	1.67	1.74	1.38	1.86
10. ...talk/write persuasively to non-specialists?	*2.10*	1.98	2.45	1.68	2.57	*0.87*	1.00	0.77	0.75	0.93
11. ...use computer software to present information?	*2.48*	2.38	2.32	2.86	2.29	*1.50*	1.52	1.58	1.31	1.50
12. ...use a foreign language?	*0.54*	0.69	0.48	0.45	0.43	*0.48*	0.23	0.65	0.62	0.79
13. ...make a judgement to a deadline, involving complicated and conflicting information?	*2.09*	2.19	2.48	1.69	1.71	*1.10*	1.25	1.10	0.79	1.36
14. ...elicit and evaluate the opinions of others before coming to a decision?	*2.09*	2.04	2.26	1.93	2.21	*0.97*	1.00	0.94	0.93	1.07
15. ...take responsibility for a decision which affects other people?	*1.92*	2.27	1.68	1.21	2.71	*0.61*	0.71	0.45	0.55	0.79
16. ...manage your time between a number of overlapping tasks?	*2.85*	2.83	2.87	2.76	3.00	*1.95*	1.85	2.06	1.97	2.00
17. ...consider the cost implications of your actions?	*1.90*	2.06	2.19	1.46	1.64	*0.54*	0.51	0.48	0.61	0.64
18. ...consider the market and the competition when making a decision?	*1.20*	1.33	1.52	0.86	0.86	*0.30*	0.19	0.32	0.24	0.79
19. ...consider aspects of health and safety at work?	*2.18*	2.40	1.23	2.55	2.79	*1.89*	1.58	2.16	2.00	2.21
20. ...consider the environmental consequences of your actions?	*1.65*	2.19	0.68	1.90	1.50	*1.54*	1.50	1.61	1.45	1.71
21. ...search out information using library facilities?	*1.95*	1.73	1.29	3.00	2.00	*2.54*	2.69	2.71	2.21	2.36
22. ...plan and/or conduct a search for relevant information using computer databases?	*2.02*	1.88	1.55	2.90	1.71	*1.58*	1.44	1.84	1.48	1.57
AVERAGE	*2.04*	2.06	1.93	2.03	2.16	*1.29*	1.29	1.35	1.20	1.39

end of the scale, "use a foreign language" (**12**) and "consider the market/competition when making a decision" (**18**) emerge as the least important of the actions in the working lives of these graduates.

Turning to how well the respondents feel their degrees allowed them to 'get' the ability to perform the actions **1-22**, the ability to "search out information using library facilities" (**21**) emerges as that best conveyed by chemistry courses with "writing concise reports to summarise material for colleagues" (**8**) being the only other action with a mean score greater than 2.00. At the other extreme, **12** and **18** re-appear as being actions for which courses provided least preparation. The correlation represented by actions **12** and **18** appearing jointly as the least important and least well covered actions is a general feature of the survey results made clear in a scatter plot of 'Need' *vs.* 'Get' (Figure 2). A similar approach to displaying survey results, though not for chemistry graduates, appears in another DfEE 'Alumni' report[10]. The points are distributed between the bottom left and top right corners showing, encouragingly, that the amount of preparation courses provide for using particular skills is generally in accord with the eventual usefulness of the skills to the graduates. Thus, of the top ten actions in the 'need' list (respectively, **16**, **1**, **9**, **11**, **8**, **4**, **5**, **19**, **2**, and **10**), six appear in the top ten of the 'get' list (respectively, **21**, **8**, **16**, **1**, **19**, **2**, **7**, **9**, **22**, and **20**). This suggests that when it comes to giving this group of graduates the skills they need in their jobs, their chemistry degrees do at least concentrate general skills training in the right areas.

If we assume that the graduates used a constant scale for assessing both their 'need' for a skill and their opportunity to 'get' it during their degree course, we would expect a reasonable course to be one where the numerical values for 'need' and 'get' are similar. In other words, the points **1-22** would lie close to the line of 45° slope in Figure 2. In fact, all points bar **21** ("search out information using library facilities") lie above this line suggesting that in almost all cases (though to varying extents) provision within the course could be usefully improved in order to prepare graduates better for work.

21 emerged as the only action where 'Get' (2.54, highest) exceeded 'Need' (1.95, 15th). Significantly, this was true of all occupations *except* PhD students who rated the importance of library skills at 3.00 ('Need', highest) and their preparation at 2.21 ('Get', highest), the lowest value assigned by any of the groups. These results suggest that in most situations chemistry graduates regard their library skills as more than adequate for their relatively low need for them whilst PhD students, who need these skills most, suggest there is some shortfall in the training they receive. This is an important demonstration of how groups who do not perform a particular action regularly might overestimate their ability to carry it out compared with a group who rely on it. The relatively low priority of library skills, even amongst the respondents in chemistry jobs, we take to support anecdotal evidence that much of this kind of information retrieval is performed by specialists within companies with sizeable research interests. PhD students rate action **22** (2.90, 3rd highest), using computer databases, almost as highly as **21** though with significantly less preparation. Indeed, since all groups bar teachers rate computer database searches as being of equal or greater importance than traditional library work, and score their preparation for it significantly lower, it suggests that this is an area of information retrieval which could be improved in chemistry courses.

Table 2: Recommendations for making chemistry courses better preparation for employment.

Recommended skills	*Number recommending*
Key skills	
Communication (written, oral, interpersonal etc.)	39
Computing/IT	25
Time management/organisation	9
Others (information retrieval, teamworking, problem solving)	3
Management skills	10
Business/commercial awareness	9
Chemistry skills	
Analytical	11
Practical	8
Others	
Legal (H&S, environmental, patent law)	7
Industrial experience/awareness	7
Vocational courses	5
Mathematics	3
Miscellaneous	9

Table 3: Chemical companies' perceptions of the quality of their recent graduate recruits (expressed as numbers and %)[2].

	Graduates	
	OK	**Lacking**
Scientific/technical knowledge	43 (**80**)	11 (**20**)
Practical skills	29 (**52**)	27 (**48**)
Numeracy	46 (**82**)	10 (**18**)
Interpersonal skills	28 (**56**)	22 (**44**)
Communication/presentation skills	20 (**38**)	33 (**62**)
Ability to relate to all levels	20 (**38**)	33 (**62**)
Awareness of intellectual property	18 (**34**)	35 (**66**)
General commercial awareness	11 (**29**)	27 (**71**)
Leadership qualities	23 (**46**)	27 (**54**)
Ambition and drive	44 (**81**)	10 (**19**)
Self-confidence	47 (**85**)	8 (**15**)
IT skills	47 (**85**)	8 (**15**)
Innovative thinking	22 (**42**)	31 (**58**)
General literacy	34 (**61**)	22 (**39**)
Other (please specify)..........		
Flexibility	1	1
Language skills		1
Teamworking skills		1

Prioritising key skills

We have divided the other points in Figure 2 (excluding **12**, "use a foreign language") into four areas **A-D**. The six actions included in area **A** lie close to the line which represents a satisfactory balance between 'Need' and 'Get' and would, therefore, not seem to be priority areas for improved provision. Conversely, the actions in areas **B-D** are, broadly speaking, a whole 'Get' unit deficient of the line balancing 'Need' and 'Get'. Area **B** contains the least important of the actions identified by this survey as being in need of better provision (all scoring below 2.0 on the 'Need' rating). These are:-

Area B **3** "motivate others to contribute to a particular task"
6 "appraise the performance of others"
15 "take responsibility for a decision which affects other people"
17 "consider the cost implications of your actions"
18 "consider the market/competition when making a decision"

The first three of these actions might be considered as relating to leadership and supervision whilst the last two lie in the realm of commercial awareness. The large difference in 'Need' between these latter two actions (respectively 1.90 and 1.20) suggests that issues of cost are more relevant across the full range of occupations than issues of market competition. This is true for all categories of jobs (Table 1). Cost and market issues are (obviously) less important to teachers and PhD students than to the other two (more commercial) categories but the *difference* in the 'Need' value for **17** and **18** is actually fairly uniform across all four. This observation emphasises that even in jobs where market issues are expected to be important, this importance still lags considerably behind that of costs and neither, at this stage of the 1995 graduates' careers, are paramount. Taken all together, the five actions of Area **B** would seem to be characteristic of more senior management positions which would not yet be the responsibility of graduates as recent as 1995. Whilst lack of commercial awareness and leadership skills are major concerns of industrialists (see Table 3), our survey suggests that these issues are not particularly relevant in the early years of graduate employment. Consequently, we suggest that these are not areas in which it is appropriate for chemistry courses to concentrate. They are difficult to address realistically anyway and, we suggest, are best handled through experience and training in the workplace itself.

Area **C** contains five, more important actions, all scoring above 2.00 (between 2.09 and 2.30) in the 'Need' rating. They are:-

Area C **4** "understand the perspective of others"
5 "appraise your own performance"
10 "talk/write persuasively to non-specialists"
13 "make a judgement to a deadline, involving complicated and conflicting information"
14 "elicit and evaluate the opinions of others before coming to a decision"

This list of actions includes several (e.g. **4**, **10**, **14**) which involve working with others but not with the element of leadership inherent in those featured in Area **B**. Consequently, they prove to be more routinely important to recently employed graduates and more relevant as issues in improving chemistry courses. Amongst these actions, the one involving self-appraisal, **5**, produced some interesting comments indicating a polarisation in the way students view parts of their course. For instance, only a handful of respondents recorded their recognition of the role of exam results and other assessment (e.g. in coursework, tutorials and practical write-ups) in self-appraisal. This may be an indication that the majority of students regard assessment solely as a means for the department to classify their performance. If this is indeed a widely-held belief then it would appear to be crucial that more effort be put into demonstrating the role of assessment in the process of "learning how to learn" by encouraging students to use it to guide their further study and revision.

The issue of making judgements, **13**, also prompted some interesting comments. By considering the few respondents who felt that their course *did* prepare them here, it might be possible to identify those learning opportunities which already exist within chemistry courses but which are either not being recognised, or not exploited, by most respondents. In fact, these respondents mostly quote practical project work and literature-based essay writing as means of developing skills in this area. Since all chemistry students are exposed to these tasks, it is noteworthy that so few recognise the opportunities provided. It might be interesting to know what the response would have been had the action been expressed with "deduce the correct interpretation" taking the place of "make a judgement". It is possible that those who quoted project and practical work here are the minority who recognise the role of making judgements in the sciences whereas the majority still lean towards the idea that scientific problems are resolved with a series of 'correct answers' rather than reasoned judgements. Similar examples are quoted as relevant to action **14**, mostly project work and assignments based on using the literature and/or various textbooks. Again, the identification of material in such sources as 'opinion' marks a recognition which perhaps not all students would make.

Area **D** comprises those skills most important to graduate employees (with a 'Need' rating of 2.48 or higher). Examination of the actions represented here (with the possible exception of **11**, though see below) shows how fundamental these are. Indeed, in common with many of the actions in area **C**, no department, in any discipline, would want to be seen to be producing graduates (regardless of their vocation) who were deficient in any of these key areas of 'graduateness'!

Area D **1** "update your knowledge and skills on your own initiative"
9 "contribute effectively to discussions"
11 "use computer software to present information"
16 "manage your time between a number of overlapping tasks"

Consequently, we suggest that area **D** (and to a lesser extent area **C**) reveals the types of skills we should be making sure that chemistry graduates possess. Furthermore, because of the fundamental intellectual nature of these skills, we suggest that there is no educational compromise involved in producing 'better' *graduates* who would also benefit industry by being 'better' *employees*.

The inclusion of action **11** here is a clear indication of the proliferation of computers in all spheres. Most respondents quoted practical and project write-ups as examples of the chance to practise this action but relatively few thought they had received any specific training. (Quite a number of comments referred to having acquired these skills by attending external courses, self-teaching, taking advantage of industrial placements or spending time at universities elsewhere in Europe.) We noticed some dependence on the university which respondents attended; the value for the extent of preparation ranged from 0.80 (worst) to 1.83 (best) when analysed by department. This probably reflects the different extents to which computers have penetrated the various courses; both in the sense of being available for students to use and being exploited by the content of the course itself (and this situation may have changed at the institutions involved as computer access has widened). However, this would appear to be an area which departments will want to continue to give attention to particularly as, in the open comment sections (see the responses to the second question summarised in Table 2), computing/IT skills come second only to communication skills amongst the suggestions for additional job-related skills which degree courses might include. The area of IT (as represented by actions **11** and **22**) is an example where *employer* and *employee* opinion differs markedly. Indeed, Tables 2 and 3 suggest that employees are more concerned about their IT skills than their employers are (though employers are more likely to be older and less computer literate themselves)!

Improving key skills provision

The survey itself provides pointers towards *how* skills such as those in areas **C** and **D** can be addressed more effectively. We shall look briefly at two areas - teamworking and communication.

Action **2** clearly relates to teamworking and the survey responses place it in area **A**, implying adequate coverage. This contrasts, however, with the rating of some of the other actions also involved in teamworking. Typical examples would be **3**, **4**, and **9**, which lie in areas **B**, **C**, and **D**, respectively. Consequently, the initial impression that teamwork is adequately covered in chemistry courses, from **2**, must be tempered by the additional information that whilst students may have experience of "working in small teams to perform tasks", they have not concurrently acquired adequate experience in "motivating others..", "understanding the perspective of others" or "contributing effectively to discussions". Our interpretation of these observations is that most respondents recognise things such as joint practicals and tutorials as instances of working in small teams, and register this experience accordingly. However, these experiences are more often cases of sharing equipment, or rooms, rather than genuine discussions, debate, and sharing of chemical knowledge. In other words, the teamwork which students experience is not as good a reflection as it could be of the kind of teamwork which will be useful to them later. Examining responses to clusters of related actions, in this way, reveals much more than a single question on a skill might. In this case, the suggestion of students experiencing more *realistic* teamwork (necessarily involving a range of perspectives and discussions) has emerged as one way of preparing students better for the situations of the workplace.

Oral and written communication are represented by actions such as **7** and **8**, respectively, and both lie in area **A**. However, the additional comments of employers (Table 3) and the graduates themselves (Table 2) contradict any suggestion that communication skills are adequately dealt with in chemistry courses. Again, we suggest that the reasonably high 'Get' values for actions **7** and **8** show that respondents are acknowledging that their courses involve them in considerable amounts of writing (lab reports, essays etc.) and speaking (tutorials, special projects etc.). However, the general desire for better communication skills (Tables 2 and 3) shows that these experiences are not entirely relevant to the types of communication skills needed at work. Some evidence for this comes, again, from considering other relevant actions such as **9** and **10** which most respondents recognise as being under-developed in their courses.

Conclusion

From the responses to this questionnaire and, particularly, the additional comments offered by some respondents, it is clear that chemistry degrees can provide opportunities to acquire the skills needed in performing all 22 actions included in the survey, though to a greater or lesser extent. Faced with information on the relative importance of these various skills, departments must decide whether or not they regard these key skills as being sufficiently important to do any or all of the following:

- *Draw attention* more effectively to the existing key skill learning opportunities which are currently not being recognised by many students. We have introduced key skills logbooks with the aim of helping students to recognise and exploit opportunities in the course. (Similarly, our findings back up the Dearing recommendation (Recommendation 21[9]) for producing "programme specifications" which draw attention to learning outcomes in the area of content *and* skills for all courses.)
- *Create more opportunities* for skills development, perhaps by targeting some of the deficiencies revealed in surveys of the type reported here. This might include using alumni and industrial contacts in order to ensure that skills are developed in relevant contexts[7, 11].
- *Increase the emphasis* on skill development by including more specific training rather than just providing the chance to practise.

Our approach to resolving the apparent dilemma presented by the need for both chemistry content and key skills is to teach more of the content in ways which simultaneously develop skills[7] and we feel that this approach can improve the teaching of content *per se*.At a time when all subjects are promoting their key skills content, it is important that chemists exploit fully the opportunities their discipline provides.

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