Making students eat their greens: information skills for chemistry students

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Abstract

Employers are increasingly requiring a range of "soft" skills from chemistry graduates, including the ability to search for and critically evaluate information. This paper discusses the issues around encouraging chemistry students to engage with information skills and suggests curricular changes which may help to "drip-feed" information skills into degree programmes.

Introduction

Today's chemistry graduates face an increasingly complex jobs market, with employers looking for a range of transferrable "soft" communication and information skills alongside subject knowledge and laboratory practice (Lawal 2001; Wallace 2003; Runquist and Kerr 2005; Hanson and Overton 2010; Windsor et al. 2014). The American Chemical Society (2015) notes that:

> "Essential student skills include the ability to retrieve information efficiently and effectively by searching the chemical literature, evaluate technical articles critically, and manage many types of chemical information" (p17)

These skills are included within the Joint Information Systems Council (JISC) concept of Digital Literacy, defined as "the capabilities which fit someone for living, learning and working in a digital society"(Joint Information Systems Council 2014). This has been adopted by the UK's Higher Education Academy (2015)as one of the key areas for enhancement in Higher Education. JISC identifies seven elements of digital literacy which should be embedded into all degree programmes. They cover a broad range of critical and evaluative competencies as well as the more technical aspects of effective use of Information technology. The elements are:

- Media literacy
- Information literacy
- Learning Skills

- Digital Scholarship
- Information and Computer Technologies (ICT) literacy
- Communications and collaboration
- Career and identity management

The first three of these elements cover skills competencies such as searching for information, critically appraising its reliability and usefulness for a particular purpose and collating it into written work, eventually allowing the students to participate in digital scholarship. This paper groups these skill-sets under the broad heading of "information skills", which also incorporates traditional library skills such as citing and referencing and plagiarism prevention. Although these competencies are vital for employability and further study, chemistry undergraduates often consider them peripheral to their interests and do not engage with them (Sunderwirth 1993; Paulson 2001; Gallagher and Adams 2002). Particularly, chemistry students have been observed to adopt a surface learning approach to information searching, being more likely than most to engage in quick-and-easy methods such as Google rather than more targeted searches covering higher quality resources such as library databases (Salisbury et al. 2007). This can become problematic in employment, as information skills are often required by employers and seen as a skills deficit by chemistry graduates in the workplace (Hanson and Overton 2010; Meyer et al. 2011). A survey for the Royal Society of Chemistry (Purcell et al. 2008) found that "research skills" (finding and interpreting information) were mentioned frequently by employers as skills needed by chemistry graduates but practically never by the undergraduates surveyed.
This study focuses on the attitude of chemistry students to information skills, the role of information skills in chemistry education and the issues surrounding embedding them in undergraduate curricula.

Chemistry courses at the University of Bradford

The University of Bradford has been running chemistry courses since the university was granted its charter in 1966. The suite of chemistry courses have recently undergone periodic review with a view to updating and rationalising the course structures, and much of the work in this paper arose from the reflection surrounding this process. The School of Chemical and Forensic Sciences previously offered 19 BSc and MChem courses, recruiting between 100 and 120 students per year. The Chemistry 4 programmes were a suite of vocational courses with a strong focus on specific training for the practice of chemistry in

major employment sectors including pharmaceuticals (drug discovery and medicines development), analytical science and the forensic sector. The school also ran multi-disciplinary courses such as chemical, pharmaceutical and forensic sciences and forensic and medical sciences. BSc Integrated Science is housed within the school and integrates chemistry, engineering and computing. Finally, the school ran traditional single honours courses in chemistry (BSc or MChem) and forensic sciences (BSc).

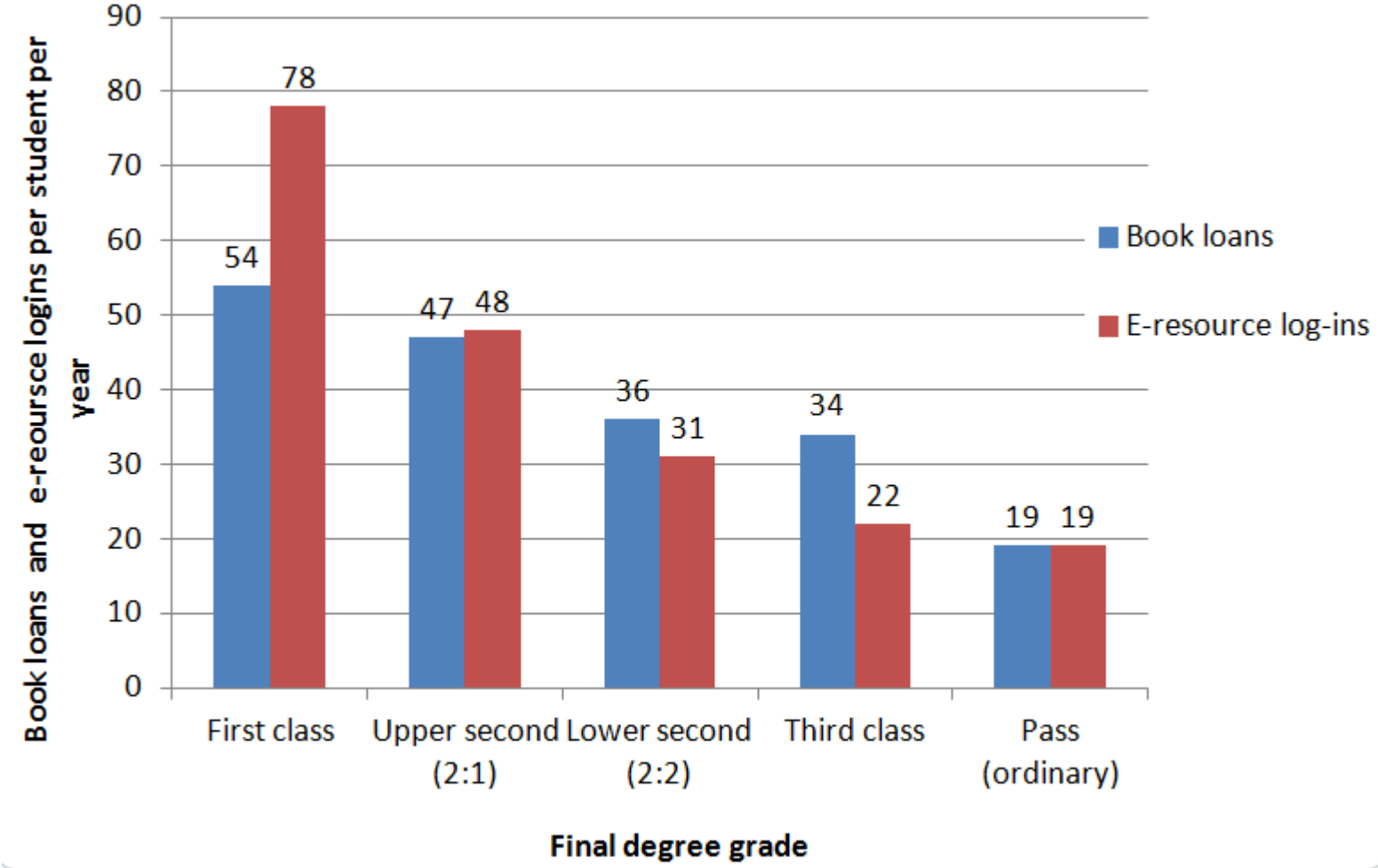
The University of Bradford recruits students from a wide range of educational backgrounds, including both traditional routes such as A'levels and newer courses such as BTECs and access courses[1] (UCAS 2016). In addition, there is a large intake of international and European students, who will have a different educational background and for whom English is not their first language. The challenge faced by staff is to ensure that the curriculum imparts the necessary skills to all of these students, supporting those for whom information skills are most challenging whilst still engaging those with more experience, and also fitting all of these "softer" skills into a full curriculum without sacrificing subject content.

Library resource use and degree grade

A source of information on the engagement of students with information skills that has not yet been widely discussed with regards to chemistry comes from the Library Impact Data Project (Stone and Ramsden 2013). This was a project led by the University of Huddersfield utilising a 3-year window of data (2005-2008) from eight UK Higher Education institutions, including the University of Bradford. It examined the possibility of a link between use of library resources (borrowing books, logging into electronic books and journals and visiting the library) and final degree grade. The project found a strong correlation (though they emphasize this does not prove causation) between degree grade and books borrowed and e-resource logins but none with library visits. Their headline findings are shown in Figure 1 below.

[1] A-levels are two-year courses generally focussed on traditional "academic" disciplines and assessed by examination. BTECs (Business and Technology Education Council awards) are more practical, vocational qualifications often assessed by work-based learning. Access courses are run by Universities and other Higher and Further Education providers to allow learners with a non-traditional education background to enter degree courses.

Figure 1: Book loans and e-resources plotted against final exam grade. Example data from the Library Impact Data Project (Adapted with permission from Stone et al. 2012: figure 2)[2]



[2] A first class degree is roughly equivalent to a US GPA of 3.7, a third class roughly equates to GPA 2.5. For more on the equivalence of UK to US degree grades, please see National College for Teaching and Leadership (2015)

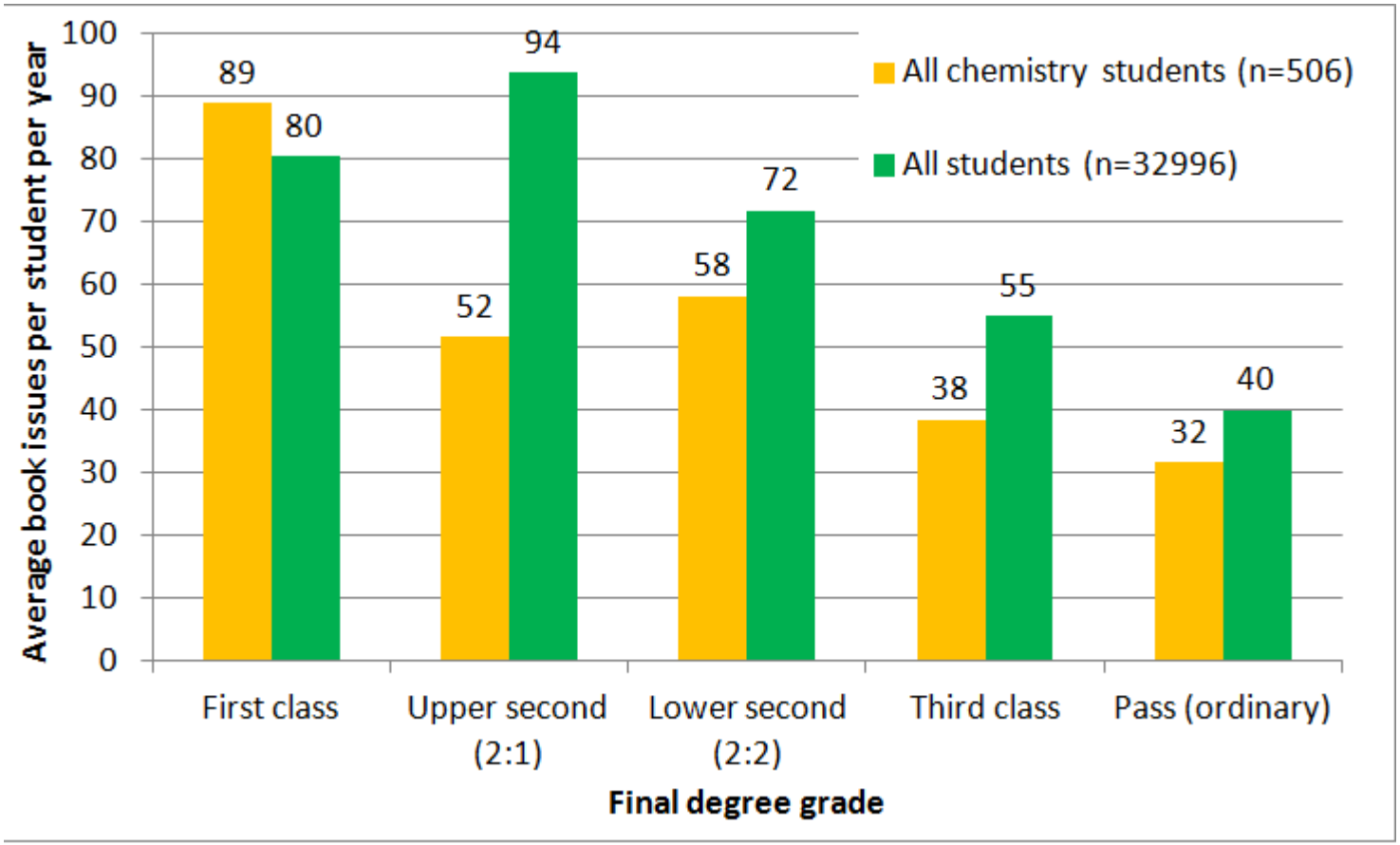


Figure 2: Book issues for chemistry and forensic students and all students plotted against final degree grade (data used with permission from Pattern 2011)

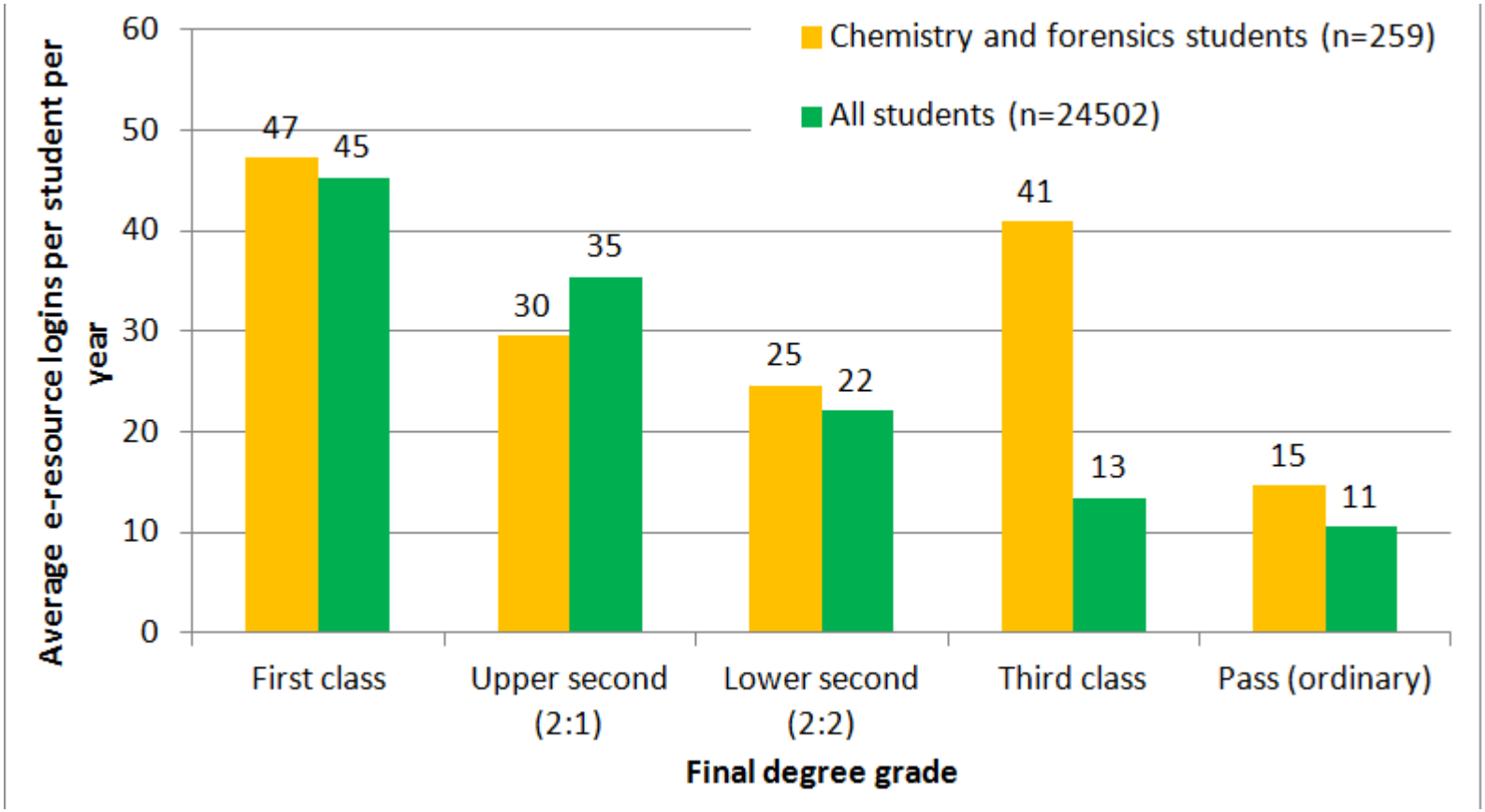


Figure 3: E-resource logins for chemistry and forensic students and all students plotted against all final degree grade (data used with permission from Pattern 2011)

The data (Pattern 2011)for students of chemistry and related courses at all institutions[3] is shown plotted against the results for all students in figures 2 (book issues) and 3 (e-resource logins). The correlation between degree grade and book issues is still quite clear, though with a slight rise between 2:1 and 2:2. The data for e-resource logins is much less clear-cut, with a large spike in the number of logins to students with 3rd class degrees. Given the well-documented preference of physical science students for electronic resources (Meyer et al. 2011; Collins and Stone 2014; Chrzastowski and Joseph 2015) this pattern is highly surprising and worthy of further study. We would hypothesize that weaker students tend to have a more "scattergun" approach to information searching, using Google to search rather than library databases. This approach would involve logging separately into each individual article downloaded rather than once per database. Weaker students might also have a less focussed approach, logging into and downloading a large number of papers rather than optimising their search strategy and concentrating on a few highly relevant papers. Certainly, the authors' observations support this hypothesis, as we have observed the tendency for weaker dissertations to have long but barely relevant reference lists. Harwood and Petrić (2012) give many examples of this phenomenon, and most academic writing guides (eg Redman and Maples 2011: 74; Greetham 2013: 171) warn against long, unfocussed bibliographies.

Information skills and chemistry curricula

The difficulty of embedding "soft" skills in chemistry curricula is widely discussed in the literature, with the main focus on writing and critical thinking skills (Sunderwirth 1993; Wilson 1994; Rossi 1997; Oliver-Hoyo 2003; Windsor et al. 2014; Stephenson and Sadler-McKnight 2015). There is also a substantial body of literature on library and information skills (Gallagher and Adams 2002; Walczak and Jackson 2007; Forest and Rayne 2009; Gawalt and Adams 2011; Tomaszewski 2011; Bruehl et al. 2015; Ferrer-Vinent et al. 2015), mostly from US institutions. There is evidence from the literature (Meyer et al. 2011) that chemistry students have been less likely than those from many cognate disciplines to recognise online journals as "library resources". They are thus less likely to see the point of instruction in library skills. The traditional approach to embedding "soft" skills within the curriculum has been to place them in single standalone modules such as personal and

[3] This includes Chemistry, Forensic and Analytical Science, Forensic Science, Applied Science and Forensic Investigation, Crime Scene Science and Chemical, Pharmaceutical and Forensic Sciences

professional development, often delivered in one session in the first year. Most of the literature on embedding information skills into chemistry courses describes this approach (among the most recent of this considerable body of literature are Liotta and Almeida 2005; Gawalt and Adams 2011; Joint Information Systems Council 2014; Mandernach et al. 2014; Bruehl et al. 2015; Ferrer-Vinent et al. 2015). However, a common experience (Kneale 1997; Lee and Wiggins 1998; Parker et al. 2005) is to find that students who need the instruction most are the ones who engaged least, considering information skills to be peripheral to their main area of interest. There are fewer articles describing embedding information skills throughout the curriculum (Walczak and Jackson 2007; Hanson and Overton 2010; Windsor et al. 2014; Jacobs et al. 2015; Yeagley et al. 2016), which is the approach we examine in this paper.

Although many chemistry undergraduate courses have begun to incorporate more written work into the first years of their courses, a significant number still have little substantial written work until the third year (Bunce and VandenPlas 2006). Table 1 shows that, of the 54 single honours BSc Chemistry courses running in the United Kingdom in 2015 (Unistats 2015), 21 (39%) have less than 25% of "coursework" in the first two years of the course. This definition of "coursework" can include in-class tests and laboratory notebooks, so does not necessarily mean that students are engaged in writing substantial pieces of work.

	<10% assessed by coursework	11-25% assessed by coursework	26-50% assessed by coursework	51-75% assessed by coursework	>76% assessed by coursework
Year 1	13%	26%	35%	26%	0%
Year 2	15%	24%	46%	15%	0%
Year 3	7%	17%	44%	30%	2%
Year 4	0%	33%	33%	17%	17%

Table 1: Percentage of single-honours BSc chemistry courses assessed by coursework (n=54, produced from data derived from Unistats 2015)

Laboratory notebooks are highly structured and require little in the way of collation and assessment of information, something that might be seen as traditional library skills in the social sciences or humanities. It is, however, standard for students to produce a substantial dissertation in their final year. Even when science A'levels (taken between the ages of 16 and 18) included large essay-based assignments this dissertation was a major step-change in

the students' educational experience, with the students writing their biggest piece of prose at the same time as engaging with concepts such as literature searching, referencing and plagiarism avoidance and an unfamiliar topic. With today's A'levels being more exam-based, students may not have written essays since they were in secondary education (under the age of 16). The dissertation is thus not only an order of magnitude larger and more complex than anything the students have produced before, but the act of writing prose is a skill they have largely forgotten, if they ever mastered it.

At the University of Bradford, the students are allowed to submit a number of drafts and receive feedback from their supervisors but many students do not fully engage with this process. Many of the resulting dissertations show problems with extensive quotation and poor collation of information. Student feedback indicates that they find the process of dissertation a very stressful and alien experience. In an attempt to address this, the dissertation module was modified in 2013 to include lectures from the subject librarian on academic writing, referencing and plagiarism avoidance. However, the impact of this change has been slight, with those students who need the instruction most engaging least.

University of Bradford chemistry student attitudes to transferrable skills

The literature reviewed in the previous section hints at the problems of getting students to engage with transferrable skills. In an attempt to quantify this phenomenon amongst University of Bradford chemistry students, we carried out a simple survey amongst our chemistry students about their attitudes to various skill-sets and how important they deemed them to be for various scenarios. The skill-sets were defined in the survey as:

- Employability skills (writing CVs, presentation skills, group work)
- Laboratory skills
- Library skills (finding information, assessing its reliability, referencing)
- Subject knowledge

The scenarios were importance for their current course, further study and employability. For each scenario, the students both rated the importance of the skills-sets (as very important, slightly important, not very important or completely unimportant) and placed them in priority order.

The surveys were handed out on paper at the end of lectures during the autumn term of 2015, after a smaller pilot with a group from year 2 in April 2015. To ensure there was no

feeling of coercion and to comply with ethical guidelines there was no check on completion and only the bare minimum of demographic information (course and level) was collected to ensure absolute anonymity. This meant that coverage was patchy but that students were not identifiable from their responses, which is generally held to encourage more honest opinions (eg University of Sheffield Learning and Teaching Services 2014). Table 2 shows that the students surveyed were from all levels of the chemistry programmes, though concentrated in levels one and two. Students from forensic programmes and integrated science (from which there was a single response) undertake considerably more written work in the first and second years of their courses than their peers on the chemistry courses.

	Number of students surveyed by course and stage (total number of students in brackets)			
	1	2	3	4
Chemistry	64 (94)	54 (78)	3 (85)	2 (50)
Forensics	5 (37)	5 (30)	0 (13)	0 (4)
Integrated Science	0 (22)	1 (12)	0 (17)	0 (0)

Table 2: Number of students surveyed by course and stage

Table 3: Students' rating of importance of various skills types (135 responses)							
		Very important	Slightly important	Not very important	Completely unimportant	% choosing very important	% choosing not very important or completely unimportant
Current academic work	Employability	74	49	10	1	54. 8%	8. 1%
	Lab skills	107	27	0	0	79. 3%	0. 0%
	Library skills	57	63	14	0	42. 2%	10. 4%
	Subject knowledge	118	16	0	0	87. 4%	0. 0%
Employment	Employability	121	12	0	0	89. 6%	0. 0%
	Lab skills	80	49	5	0	59. 3%	3. 7%
	Library skills	28	67	34	5	20. 7%	28. 9%
	Subject knowledge	99	33	2	0	73. 3%	1. 5%
Future study	Employability	84	37	11	2	62. 2%	9. 6%
	Lab skills	89	42	3	0	65. 9%	2. 2%
	Library skills	56	55	21	2	41. 5%	17. 0%
	Subject knowledge	115	18	1	0	85. 2%	0. 7%

Table 3 shows the results of the survey, with numbers and percentages of students rating each of the four skill-sets as very important to unimportant for their current academic work, employment and future study. Most students rated library and information skills (finding information, assessing its reliability, referencing) as very or slightly important, the percentage choosing "very important" was lower than for all other skill types in all categories. Subject knowledge came top in their ratings for current and future academic work, with employability skills coming top in importance for future employment.

Table 4: Students' ranking of importance of different skills types (135 responses)

		Average rank (4 being most important)	% of students choosing 4 (most important)	Number of students choosing 1 (least important)
Academic work	Employability	2. 6	32. 1%	21. 5%
	Lab skills	2. 7	20. 1%	10. 4%
	Library skills	1. 9	11. 2%	51. 9%
	Subject knowledge	3. 2	56. 0%	12. 6%
Employment	Employability	3. 2	59. 0%	12. 6%
	Lab skills	2. 5	15. 7%	12. 6%
	Library skills	1. 8	15. 7%	61. 5%
	Subject knowledge	2. 8	26. 9%	9. 6%
Future study	Employability	2. 6	37. 1%	26. 7%
	Lab skills	2. 6	22. 0%	13. 3%
	Library skills	2. 1	15. 9%	40. 0%
	Subject knowledge	3. 0	42. 4%	14. 1%

Table 4 shows that, when asked to rank the skills types, the pattern was similar, with subject knowledge being rated as the most important for current and future study and employability as the most important for employability. Library and information skills again came at the bottom in each category

This small sample shows that, whilst students generally rate library and information skills as very or slightly important, when asked to rank them against other skills such as employability, laboratory skills or subject knowledge, they consistently come last. This implies that struggling students would be more likely to de-prioritise information skills as they are perceived to be least important part of their course. As various studies have shown that they are in fact important in their future careers (Purcell et al. 2008; Hanson and Overton 2010) this poses a challenge to those designing curricula to attempt to increase students' engagement with information skills.

Incorporating information skills into the chemistry curriculum.

The literature reviewed suggests that many chemistry courses still address the issue of imparting "soft skills" by introducing them in a single standalone module or course, often in tandem with little written work until the final year dissertation. We would suggest that curricula move from this "sudden death" introduction to academic writing to a steadier "drip-feed" of information and writing skills. This could be done by embedding information skills in subject modules at every level, introducing skills of increasing complexity in each level. Table 6 shows the scheme proposed for the new University of Bradford chemistry curriculum, embedding information skills into each level of study ((Quality Assurance Agency for Higher Education 2008).

Table 6: Scheme for embedding information skills

Year[4]	Information skills	Teaching method	Assessment method	Other skills
Year 1	• Find relevant information • Assess information • Present information orally	• Team-based learning	• Group presentation on "hot topic" in chemistry	• Group work • Presentation skills • Awareness of current developments in chemistry
Year 1	• Basic plagiarism awareness • Concept of referencing	• Blended learning	• Online quiz on plagiarism and referencing	
Year 2	• Structure searching • Reference sources • Bibliographic software	• Hands-on workshops	• Search strategy • Annotated bibliography	• Structure drawing
Year 2	• Analyse information • Collate information into written work • Reference sources • Intermediate plagiarism awareness	• Hands-on workshops • Independent study	• Mini-project • Annotated Turnitin draft	• Produce substantial piece of written work • Paraphrasing • Develop students' own

[4] Year 1 equates to FHEQ level 4, through to year 4 / MChem level equating to FHEQ level 7

				interests within subject
Year 3	• Analyse current research • Produce major piece of written work • Advanced awareness of good academic practice	• Lectures • Blended learning • Independent study	• Literature-based project on staff research interest	
Year 4: MChem	• Advanced writing skills • Link between laboratory and written work.	• Independent study	• Laboratory-based project	• Laboratory skills

The most basic information and writing skills centre around being able to find relevant information, assess its relevance and present it in a way that answers the question. These can be inculcated along with other "soft skills" such as team work and presentation skills in a group presentation on a "hot topic" in chemistry. The students can be encouraged to assess the relevance and reliability of information sources in team-based learning sessions, (Tweddell 2013) then produce an assessed presentation. This shows students the relevance of information skills at an early stage, in addition to introducing them to employability skills such as presentation and group work. We would suggest little formal referencing is needed at FHEQ level 4 but an online quiz about good academic practice (such as University of Bradford Library 2014) would help to introduce students to concepts of referencing and plagiarism avoidance.

The next level of skills involves analysing information and collating it into a substantial piece of work, also introducing formal referencing and emphasising plagiarism avoidance. These can be combined with the subject-specific skill of structure searching. Analysis of information and referencing can be assessed by way of an annotated bibliography exercise, where the students search for an unknown structure and find literature on synthesizing the compound. They submit a search strategy and a bibliography produced using bibliographic software such as Endnote, Refworks or Zotero. The bibliography is marked on the accuracy of their search and the relevance of results. This should provide a low-stress introduction to producing written work and inculcate good academic practice by emphasising paraphrasing, referencing and plagiarism avoidance. Also linking the structure searching to a bibliographic exercise shows the direct relevance of information skills to chemistry practice. The

introduction of bibliographic software highlights its usefulness in numeric referencing formats, and follows feedback from Bradford MChem-level students that Endnote is invaluable when they come to write major projects, allowing them to organise their resources and edit their work without endlessly re-numbering their citations, and that they wished they had encountered it earlier in their studies.

At the same level, collation of information and the production of a substantial piece of written work can be assessed by means of a mini-project. The project assesses skills of information searching and collation and also writing skills. In addition to the project, the students submit a preliminary draft to Turnitin (TurnitinUK 2015). The students then produce a critique of the Originality Report, highlighting unattributed quotations, inadequate paraphrasing and other areas of poor academic practice. This builds their awareness of poor academic practice within their own work.

These preliminary exercises should enable a more gradual transition into major projects in the third and final years of degree programmes.

Summary

Information skills are vital to enable graduates to function in the 21st century jobs market, but chemistry students often see these are peripheral to their interests and are unwilling to engage with them, taking fast and easy options for information searching wherever they exist. Our job as educators is to persuade them that this “fast food” option is not good for their long term prospects and to instead show them that the “healthy eating” approaches imparted in information skills sessions are worthwhile.

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