The ability of beginning university chemistry students to use ICT (information and communication technology) in their learning in 2002

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Abstract

There is an assumption that high-school students are becoming more computer literate, but published studies of specific skill level are lacking. An anonymous multiple-choice survey self-assessed the ICT (information and communication technology) skills of first-year chemistry students at the beginning of 2002. The general level of ICT skill continues to improve. There are minor deficiencies in the use of word processors, email attachments, the WWW, and in metacognitive skills. There are significant deficiencies in the use of spreadsheets, library databases, presentation software and computer conferencing, with major deficiencies in the use of relational databases.

Introduction

Universities are making increasing use of ICT (information and communication technology) in teaching and learning: eg (*1,2*). The Australian Chamber of Commerce and Industry (ACCI) and the Business Council of Australia (BCA) have identified basic ICT skills as part of the framework of employability skills for the future (*3*): also see similar reports (*4-6*). Within the area of chemical education, Swift and Zielinski have identified the following as important ICT skills for undergraduate chemistry students (*7*): electronic record keeping; word processing; spreadsheets; (relational) databases; bilbliographical databases; computer programming; instrument interfacing; information retrieval using the World Wide Web; and information retrieval from electronic journals, patent information and other specialised databases. Other researchers have also added the use of spreadsheets, electronic mail, computer conferencing, symbolic math software, molecular modeling software, graphing calculators, and simulation software to the list of desired skills (*8-12*). There have been several other publications on the importance and use of ICT in chemical education, of which (*13-19*) are a small selection. All of these publications implicitly assume that high-school students in the Western world are computer literate: in fact, (both federal and state) Australian government policy relies on this premise (*20*). However, informal discussion at the Chemical Education sessions of the 2000 *RACI National Convention* suggested that there is a significant number of university chemistry students who are less computer literate than politicans and university administrators assume. If students do not have the required level of ICT skills, then discussions on pedagogical issues related to ICT usage in the chemistry (or any) curriculum are moot. This paper is the third in a series, which seeks to provide numerical data (as opposed to assumption) about the actual level of specific ICT skill of students in the author's first-year chemistry class at Deakin University: previous papers addressed student skill levels in 2000 and 2001 (*21,22*).

This paper is the written version of a paper presented at the 2002 RACI Division of Chemical Education National Conference *Rejuvenating the Learning and Teaching of Chemistry*.

The study methodology

This study is based on student's self-assessment of their ICT skills, using an anonymous multi-choice survey instrument in the first week of the academic year. It can be argued that such survey instruments measure the level of student confidence in ICT usage, which according to academic staff, teaching ICT courses, *over*-estimates the actual level of ICT skill (*23*). Furthermore, data from the University of Sydney showed that students in science-based faculties had more previous computer experience than the university average (*24*). Hence, the results of the project from this year and previous years (*21,22*) should *over*-estimate the true ICT skill level across the university. In other words, the hypothesis of study is:

(All) university students' true ICT skill level
$\leq$ Science (chemistry) students' true ICT skill level
$\leq$ chemistry students' perceptions of ICT skill.

The respondents were asked to agree or disagree with a number of statements using a 4-point Likert scale. Students were questioned about their general ICT competency, eg:

'I can use word-processing programs',

as well as more detailed questions about particular ICT skills, eg:

'I can insert tables in word-processing programs',

'I can use "styles" in word-processing programs.'

Some questions included information about the skill being assessed:

'**http://FirstClass.deakin.edu.au/Login/** is a World Wide Web address or URL. I can use Web addresses or URLs.'

The survey instrument is similar to that used in previous years: the instrument used in 2000 can be found in (*21*).

Results and discussion

The survey sample group

The survey sample group consisted of the author's first-year chemistry class at Deakin University. In 2002, this unit had approximately 100 students majoring in biological sciences, biotechnology, chemical sciences, forensic science, wine science, and some other disciplines: 49 students responded to the survey. This cohort consists entirely of "on-campus" students. Reporting of the responses to the nearest percent has resulted in some round-off error (eg in Table 3, 10% + 17% = 26%). Binomial-distribution standard deviations are reported in the Tables.

This first-year class consisted mainly of students (80% of respondents) in their first year of tertiary education, but a significant number had some previous tertiary education (10% in 2nd year, 2% in 3rd year, 8% in higher years). Students in 2nd and higher years of tertiary education did not have higher skill levels than 1st year students.

Although students in science-based disciplines are perceived to have a greater need of ICT competency, Lawson and de Matos have shown that a high level of ICT competency is also required of graduates in the humanities (*25*).

Survey Analysis
The survey was printed on a single A3 sheet in the form of a four-page "booklet" and responses were manually keyed into a computer for analysis. All analyses were done manually with standard statistical methods and formulas (*26,27*), using *MS Excel* for the calculations and data management. Tabulated uncertainties are one standard deviation based on the binomial distribution (students do or do not have the skill). On-line assessment was deliberately *not* used, as the survey results would be biased by students who are more computer literate.

There was a very small number of responses (< 1%) which did not choose one of the four multiple-choice responses (Likert scale: 1-4): in most of those cases, there were written comments on the survey, which indicated that the student did not have that particular skill and responses of 1 (strongly disagree that 'I can …') were recorded.

There were a small number of responses (< 1%), which chose two multiple-choice responses (eg both '2' and '3'), for a particular question. These cases were interpreted as the more-ICT-literate response in subsequent analyses for the following reason. The aim of the study is to determine deviations away from the assumption that students have ICT competency. Since we are effectively using a 'proof by contradiction' to challenge the assumption, the interpretation of these ambiguous responses as the more-ICT-literate response is equivalent to extending the 'greatest lower bound' of the set of students who have that particular ICT skill.

Responses '3' and '4' (agree or strongly agree that 'I can …') are combined in the following analyses as having the (self-) assessed knowledge or skill. Likewise, responses '1' and '2' are combined as not having the knowledge or skill.

Basic ICT skills
The ACCI and the BCA have identified that basic graduate ICT skills would involve the use of programs such as Word, Excel, PowerPoint and Lotus Notes, which are part of the everyday communication processes, and the use of programs to manage production processes (*3*). Educational institutions would add WWW-related skills, electronic-mail skills, computer-mediated communication (conferencing) and using library databases/catalogues to the list, because of the utility of these skills for research and on-line flexible teaching and learning (*7,16,28,29*). Table 1 shows that *most* students have the skills required by employers and educational institutions, but there are some significant deficiencies.

All students reported being able to use word-processing software. Approximately 90% of students have the ability to use the WWW and electronic mail. These high levels of competency reflect the three types of software most commonly used in the high-school environment (*24,30*).

There is a significant drop in the level of ability to the remaining 'basic' software categories: spreadsheet, library catalogue/database, presentation software, computer conferencing and relational database.

Collaborative software (eg Lotus Notes) skill was not investigated.

Table 1: Percentage of students having ICT skill to use a particular software type

Software type	2000	2001	2002
Word processing	99	98	100
Electronic mail	85	92	92 ± 4
World wide web	87	94	88 ± 5
Spreadsheet	88	77	80 ± 6
Library database	(a)	(a)	76 ± 6
Presentation software	(a)	(a)	63 ± 7
Computer conferencing	20	30	35 ± 7
Relational database	(a)	(a)	23 ± 6

(a) Not all 'basic' skills have been surveyed.

Implications for general university teaching and learning

Report and essay writing
Report and essay writing skills are essential in the university setting (*31,32*). However, unlike the humanities, technical writing in the sciences (including information technology, information systems and computer science) requires the use of superscripts, subscripts, special letters and symbols, equations, etc.

Table 2: Percentage of students having specific skill associated with word-processing.

Word-processing skill	Know
Insert tables	94 ± 3 %
Use 'styles'	92 ± 4 %
Insert superscripts and subscripts	78 ± 6 %
Type special letters and symbols	69 ± 7 %
Insert pictures and/or diagrams	67 ± 7 %
Insert equations	61 ± 7 %

Table 2 indicates that a significant proportion of students lack the ICT skills to write an acceptable technical report at the beginning of university.

Recommendation 1: Students should receive training in the use of word processors, with emphasis on specific skills, which are appropriate to their particular discipline.

Self-learning
One-third of students (33%) are unable to insert diagrams into word-processing documents while a larger proportion (41%) are unable to insert diagrams into presentations. The cross tabulations ('correlations') between responses yield much more useful information.

Table 3 shows 1 in 4 students (26%) are unable to transfer their skill from one situation to another: they are able to insert diagrams using one piece of software, but unable to do so using another, even though the software have the same "look-and-feel" and the same menu commands for inserting diagrams. This is consistent with a study that shows students at the start of university are unable to transfer mathematics skills from one context to another (*33*).

Table 3: Cross tabulation of skill of inserting diagrams/pictures using different types of software.

Insert diagrams in presentations		Insert diagrams in word-processing	
		Don't know	**Know**
	Don't know	**23 ± 6 %**	**17 ± 5 %**
	Know	**10 ± 4 %**	**50 ± 7 %**

The desirability of metacognitive skills is well established in the educational literature (*34-37*). However, the time pressure for more 'academic content' usually regulates the 'teaching' of metacognitive and other study skills to the counselling and remedial tutoring services. Successful development of metacognitive skills depends on committing *class* time to skills development, and integration of this instruction both with the academic content and across the curriculum (*38*).

Recommendation 2: High school and university curricula should foster metacognitive skills, eg the ability to apply [the same] 'problem-solving strategies across a range of areas' (*3*).

Electronic submission of assignments

Most students are able to use electronic mail at the start of tertiary studies: 8% cannot. Table 4 shows that another 8%, who are able to use electronic mail, are unable to use attachments. While this is a significant improvement from 2001 (*22*), one in six students still do not have the skill for electronic submission of assignments.

Table 4: Cross tabulation of knowledge of electronic mail and skill of attaching documents.

Attaching documents to electronic mail		Electronic mail	
		Don't know	**Know**
	Don't know	**8 ± 4 %**	**8 ± 4 %**
	Know		**84 ± 5 %**

Recommendation 3: Tertiary education institutions should not assume that students can submit assignments electronically, but should first train students in this skill.

On-line teaching and learning via the WWW

Educational institutions are making increasing use of the WWW (*39*). Textbooks and printed materials often cite URLs as sources of further information, for example (*40*):

'For more information on the URLs we reference in this book … see the web page …

http://www.oreilly.com/catalog/devbioinfo/ .'

Table 5 shows that while general WWW competency is extremely high, 1 in 8 students cannot use an URL to access a web site. There has been no significant change in this skill level since 2001 (*22*).

Table 5: Cross tabulation of WWW competency and skill of using URLs.

URLs		WWW	
		Don't know	**Know**
	Don't know	**8 ± 4 %**	**4 ± 3 %**
	Know	**4 ± 3 %**	**84 ± 5 %**

Table 6 shows that 2 out of 5 students cannot limit the number of 'hits' or retrievals from the WWW by using advanced search strategies. In 2001, a similar question on keyword searches of the WWW, but omitting the qualifier about limiting number of 'hits' indicated that 90% of students had WWW search skills (*22*). The significantly different responses in 2001 and 2002 indicate that mere possession of some ICT competency does not imply proficiency or adequate skill level

Table 6: Cross tabulation of WWW competency and skill of using URLs.

Advanced search strategies		WWW	
		Don't know	**Know**
	Don't know	**10 ± 4 %**	**31 ± 7 %**
	Know	**2 ± 2 %**	**57 ± 7 %**

This inability to search the WWW *effectively* parallels unquantified observations that students are unable to evaluate the *quality* of their 'hits' or retrievals. For example, information retrieved from websites of dubious political parties in foreign countries is given the same credence as official university or reputable government websites. There also seems to be a lack of understanding of copyright, 'fair use' and plagiarism issues, but a fuller discussion (eg *41,42*) is beyond the scope of this paper.

Recommendation 4: Tertiary education institutions should provide training for students to use the WWW effectively and ethically. In some instances, this 'training' might be as simple and easy as using 5 minutes of class time to demonstrate typing an URL into the appropriate box in a web browser.

Table 7: Cross tabulation of WWW competency and skill of reading PDF files.

Reading PDF files		WWW	
		Don't know	**Know**
	Don't know	**10 ± 4 %**	**33 ± 7 %**
	Know	**2 ± 2 %**	**55 ± 7 %**

Table 7 shows that 43% of students do not know how to read portable document format (PDF or ADOBE ACROBAT format) files. Many more students probably have *unconscious* knowledge of how to access a web-linked PDF file using a pre-configured web browser. The significance of the 43% number is that if electronic teaching materials are disseminated to students as PDF via a non-WWW medium (eg diskette, CD-ROM, electronic mail attachment or electronic bulletin board), almost half the class may not know how to read the documents.

Recommendation 5: Students should receive training on how to recognise the file-name extension for PDF files and how to use the Adobe Acrobat Reader.

Numerical analysis, and plotting

The ACCI and the BCA specifically identified the use of spreadsheets in their framework of employability skills (*3*). The general competency and specific skills, associated with spreadsheet use, require improvement.

Table 8: Cross tabulation of spreadsheet competency and skill of analysing numerical data. Uncertainties are one standard deviation

		Use of spreadsheets	
		Don't know	**Know**
Use spreadsheets to analyse numerical data	**Don't know**	**20 ± 6 %**	**18 ± 6 %**
	Know		**61 ± 7 %**

Table 8 shows that 39% of students are unable to use a spreadsheet to analyse numerical data and to perform calculations.

Table 9: Cross tabulation of spreadsheet competency and skill of plotting numerical data.

		Use of spreadsheets	
		Don't know	**Know**
Use spreadsheets to plot numerical data	**Don't know**	**18 ± 6 %**	**18 ± 6 %**
	Know	**2 ± 2 %**	**61 ± 7 %**

Table 9 shows that 37% of students are unable to use a spreadsheet to plot numerical data.

The Australian high-school curricula and examination system encourages the use of programmable and graphics calculators, in preference over the use of spreadsheets. At the tertiary level, students are often encouraged to use specialised plotting (eg Origin, Igor, SigmaPlot), analysis (eg StatView, MiniTab) and other mathematical software (eg MathCAD, Mathematica). The plethora of tools compounds the problem of lack of generic knowledge and skill transfer from one context to another (*33*).

Ehrmann has implied that spreadsheets are preferred over more specialised programs, because spreadsheets are perceived as being more 'ordinary' (ie 'worldware') and easier-to-use (*43*). Most students have access to spreadsheet software at home, without incurring additional licensing cost for the student or the university. Of course, the use of specialised software may still be required for upper-year studies in some disciplines.

The last quarter century has seen a shift away from logarithmic tables and slide-rules to electronic calculators. The latest shift, to programmable and/or graphics calculators, has decreased incentive and opportunity for the use of spreadsheet software in the high school environment. This author believes that use of programmable and/or graphics calculators should be avoided in favour of non-programmable calculators and spreadsheets for the following reasons. Firstly, the 'real world' of employment and tax returns requires the keeping of records, which is easily done with spreadsheets (printing creates a hardcopy). Secondly, the framework of employability skills specifically identifies the use of spreadsheets (*3*), not programmable and/or graphics calculators. Finally, many tertiary education institutions forbid the use of programmable and/or graphics calculators in examinations: students are permitted to use non-programmable calculators.

Recommendation 6: Greater use of spreadsheet software should be encouraged at high school, and the use of programmable and/or graphics calculators should be replaced by non-programmable calculators.

Recommendation 7: The use of specialised software (eg Origin, Igor, SigmaPlot, StatView, MiniTab, MathCAD, Mathematica) should be on a needs basis. Until that stage, students should be trained in the use of generalist ('worldware') spreadsheet software, which should be used across all disciplines to foster expertise in software that are in common usage in the general workforce outside universities.

Use of library databases and presentation software

Table 1 shows that *most* students have competency in use of library databases (76%) and presentation software (63%). Nevertheless, it would be desirable to increase the skill level of these two types of software.

Recommendation 8: Students should be trained in the use of library databases.

Recommendation 9: Students should be trained in the use of presentation software.

Collaborative learning via computer conferencing

Computer conferencing, 'discussion spaces' and other forms of computer-mediated communication are beneficial for the work (paid employment) environment, distance education, and for classes that span across multiple campuses. *Most* students (55%) know *about* computer conferencing or 'discussion spaces', but Table 1 and Table 10 show that only a minority (35%) of students have competency in the use of computer conferencing. Students who are enrolled 'on-campus' and who have regular contact with fellow students and teaching staff would have less need to use computer conferencing.

Table 10: Cross tabulation of knowledge about and ability to use computer conferencing.

		Know *about* computer conferencing	
		Don't know	**Know**
Know *how to use* computer conferencing	**Don't know**	**45 ± 7 %**	**20 ± 6 %**
	Know		**35 ± 7 %**

Recommendation 10: Students should be trained in the use of computer conferencing, 'discussion spaces' and other forms of computer-mediated communication, if it is appropriate to their particular learning environment.

Relational databases

The ACCI and the BCA identified 'using IT to organise data' as a desirable element of the framework of employability skills (*3*). This is normally done using relational databases (eg Access, FileMaker).

With the vast increases in computing power over the last decade, the ability of ICT to store, sort, manipulate and retrieve vast amounts of biological data has led to the new science of *bioinformatics* (eg (*16,40*)). While bioinformatics encompasses many areas of ICT usage applied to molecular biology, the most-rapidly-growing area of bioinformatics involves the use of relational databases (eg (*16,40*)). Many of the comments here about bioinformatics also apply to data mining.

Table 11: Percentage of students having specific skill associated with relational databases.

Relational database skill	Know
Can use relational database	22 ± 6 %
Create a database	16 ± 5 %
Enter data into database	18 ± 6 %
Extract data from a database	20 ± 6 %

Table 11 shows that 76% of beginning university students have no database competency at all, and even higher numbers (80-84%) are unable to create a database, enter data into a database or extract data from a database. In addition, there is anecdotal evidence that many students (and academic staff) do not even know what a (relational) database is.

Recommendation 11: University teachers should assume that university students have no knowledge of (relational) databases. This has particular implications for the teaching of database content within ICT, bioinformatics and other courses.

Recommendation 12: University students should receive general education on what databases are, and how they can be used (*16,40*).

Recommendation 13: University students should receive training in the use of (relational) databases, with emphasis on specific skills, which are appropriate to their particular discipline.

Implications for future investigations

A Telstra-commisioned study found that there has been significant growth in access to computers and internet access within Australia, but there is significant variation across community groups (*44*). Socio-economic factors such as low family income are the primary causes of the digital divide. It is unclear how the results of studies on the general population's access to computers translate to the access to computers and ICT skills of different student groups.

There is some evidence *suggesting* that the ICT skills of science students should be better than the institutional average (*24*), but there is no *conclusive data* to confirm (or refute) this premise.

Recommendation 14: Studies, such as the one reported here, should be conducted to provide more data for the formulation of evidence-based policy.

Summary and Conclusions

This paper reports on the ICT skills of students enrolled in first-year chemistry, as evaluated by multiple-choice self-assessment. The 2002 results, presented here, indicate that the 2002 cohort have higher ICT skill levels than the 2001 and 2000 cohorts (*21,22*). However there are some deficiencies, which have significant detrimental implications for the teaching and learning practises of tertiary education institutions, and for the students' future employability.

Minor deficiencies in the use of word processors, metacognitive skills, electronic-mail attachments, and use of the WWW were identified. There were significant deficiencies in the use of spreadsheets, library databases, presentation software and computer conferencing. Major deficiencies in the use of relational databases were noted, with many students (and some academic staff) not having *any* knowledge about relational databases.

The ICT skill results, of science students presented here, are believed to be better than the institutional average (*24*). Hence, the deficiencies in ICT skills would be exacerbated across an institution.

For the most part, these recommendations will be easy to implement, with the possible exception of the two specific recommendations 2 and 6 on metacognitive skills development and use of spreadsheets (instead of programmable and/or graphics calculators, specialised statistics, mathematics or plotting packages).

The desirability of metacognitive skills is well established. Although many academic teaching staff *perceive* skills development as outside the gambit of academic coursework, integration of the teaching of such skills is essential.

Greater use of spreadsheets and non-programmable calculators should be encouraged at high school because these are the skills required by both tertiary education institutions and employers.

Finally there is a need for continued monitoring of students' ICT skills.

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Contents

* **Refereed papers**