Guide for contributors to the Australian Journal of Education in Chemistry

Introduction

The Australian Journal of Education in Chemistry publishes refereed articles contributing to education in Chemistry. Suitable topics for publication in the Journal will include aspects of chemistry content, technology in teaching chemistry, innovations in teaching and learning chemistry, research in chemistry education, laboratory experiments, chemistry in everyday life, news and other relevant submissions.

Manuscripts are peer reviewed anonymously by at least two reviewers in addition to the Editors. These notes are a brief guide to contributors. Contributors should also refer to recent issues of the Journal and follow the presentation therein.

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Articles should not exceed six pages in the printed form including tables illustrations and references - ca. 5000 words for a text only document. Short, concisely written articles are very welcome. Please use headings and subheadings to give your article structure.

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2. On another separate page provide an abstract of 50 to 100 words;
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Reference Styles

AusJEC reference styles are based on the most recent edition of the Publication Manual of the American Psychological Association OR the Journal of Chemical Education.

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In this issue .......... 

In Letter to the Editor, Lim engages in a scholarly discussion with previously published authors Petrushevski and Monkovic about the distinction between the phenomena of effusion and diffusion. As is so often the case, precision of language and of definitions are shown to be all-important. This is a most valuable role of Letters to the Editor contributions, and more are invited.

Jamie and co-directors of the Advancing Chemistry by Enhancing Learning in the Laboratory Project (ACELL) describe the development of this project from one that focussed on physical chemistry alone in the Australian scene to one that concerns chemistry across the board and is gradually expanding across international barriers. The aims and the methodology of ACELL are presented, with particular emphasis on workshops where experiments, both existing and novel, are tested and evaluated by tertiary-level teachers and undergraduates working collaboratively. The end results are documentation of the experience, feedback to experiment developers, and the development of a community of practice involving both teachers and students.

To the suite of documented APCELL experiments is one described by Price, Griffith and Wilson. The FTIR spectrum of an equilibrium NO₂/N₂O₄ mixture is measured as a function of temperature, to allow calculation of the absorbances, and concentrations, of the two reactant species. This, in turn, enables calculation of the equilibrium constant at various temperatures, and so ΔH° of the reaction. From the value of ΔG° estimated at any temperature, ΔS° can be calculated. The experiment can enhance appreciation of thermodynamic relationships, as well provide experience in FTIR spectroscopy.

In a climate of rapidly increasing adoption of flexible delivery instruction with a dependence on online learning opportunities, Molphy reports on an evaluation of a first-year chemistry course with online elements. Employing a constructivist approach, a major goal of the project was to create a learning environment that stimulated and facilitated both student-student and student-tutor discussions. The findings from focus groups suggest that major hurdles to effective participation include the psychosocial environment in tutorials, and the slow development of independent and confident learning attitudes of some students.

Given a choice, would third-year Chemistry students choose instruction via on-campus lectures, access to online learning materials, or a flexible combination of both options? Student preferences and practices are studied by McShane, Peat and Masters. Their findings are in extraordinary harmony with those of Molphy. Both suggest caution in making the transition to electronic teaching modes on the grounds of student preferences and readiness.

Stewart, Amar and Bruce from the University of Maine discuss Peer Led Team Learning (PLTL) in a general chemistry course with over 500 students. The essential elements are (i) use of active learning strategies by working in cooperative small groups so that students can exchange ideas and challenge their own knowledge, and (ii) a set of challenging, well integrated workshop materials designed to foster social interactions. There are interesting differences from the findings of Molphy and of McShane et al.

Das Sharma proposes the use of riddles as a means of presenting challenging learning situations in a motivational situation. Some examples of riddles, each with four leading questions, are presented.

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For many years I have been reading the monthly journal Australasian Science (http://www.control.com.au/) which provides me with a valuable resource for keeping abreast of developments at a general level about science and technology in Australia and overseas. I often mention this journal to colleagues. Unfortunately, few colleagues know of its existence and in some cases are even surprised to learn that such a journal exists that is concerned with a broad range of science and technology issues.

A regular column in Australasian Science is entitled 'Cool Scientist' which in one A4 page (750 words) presents a profile of the work of a professional scientist usually with an ‘action’ photograph. One recent example was an interview with Dr Steve Chenoweth (Nov/Dec 2006, 27(10),43) about his study of the sex differences in fruit flies. Another example was a discussion with Dr Emma Collier-Baker (March 2007, 28(2), 43) whose work involves the importance of stringent control conditions when establishing the mental capabilities of animals, especially primates and dogs. Other examples are the international work in Australia and Brazil of Professor Jonathan Majer (Jan/Feb 2007, 28(1), 45) involving his important studies of insects in tree canopies and the research of marine biologist Matthew Gordon (Sept 2006, 27(8), 43) who catches some of the world’s most venomous jellyfish species and follows their movements with electronic tracking devices.

As many readers of Australasian Science - certainly me - do not know what scientists do in their everyday life this is usually very illuminating reading which includes some personal aspects about how the scientist became involved in his/her work.

Related to this interest, currently I am reading a book Cultural identity in science education: its history in person, for which the editors, Kenneth Tobin and Wolf-Michael Roth, invited colleagues from a wide range of countries to write about their introduction to life and work in science education – not science. The writers are all experienced science educators – several of whom started their academic careers as scientists, some are researchers who migrated to the USA and other received their doctoral education in the USA and returned to their homeland. The 22 authors have written their own chapters in narrative form in response to questions about their participation in science/science education, examining key research foci at critical points of their careers and the importance of significant role models and peers who helped shape their approach to research and teaching. One such colleague is Professor Penny Gilmer, a Stanford-educated biochemist who, in choosing to use technology as a major theme in her biochemistry teaching at Florida State University, developed a strong collegiality in this work with science educators and subsequently completed a second doctorate in science education.

These descriptions of scientific work can be a source of guidance and inspiration for current and future scientists and science educators. What is of value in these writings is that they provide insight into how people make decisions to study science and/or science education, how some of these events are fortuitous and serendipitous – being at the right place at the right time – with, of course, having the prerequisite knowledge and skills in place for the tasks ahead.

How can we use these kinds of personal accounts in science and science education to enthuse students at all levels of schooling to be more interested and enthusiastic about science? It is sometimes interesting to learn that it is not always those who excelled in science at secondary school who end up working in science fields.

Perhaps we can start in this Journal a series that reports the work of current chemists – those working in organic, inorganic, physical, bio-, nano-, astro- and chemical education and other fields – thereby providing readers with an understanding about how our profession comes into being and progresses through the weekly and daily lives of chemists.

References

Letter on the Editor

Comment on “Alternative demonstrations of slow processes. III: A demonstration and video clip showing effusion in liquids”

Petrusevski et al. have recently published a demonstration in this Journal (1), entitled “Alternative demonstrations of slow processes. III: A demonstration and video clip showing effusion in liquids”. However, the demonstration illustrates diffusion, not effusion. (The osmosis-like characteristics of the demonstration have been discussed by Petrussevski et al. in their paper (1) and will not be discussed here.)

Chang (2) explains:
“For effusion to occur, the mean free path of the molecules must be large compared with the diameter of the orifice [pinhole]” (p 54 of Ref. 2), where the mean free path is the distance moved by a molecule’s centre of mass between collisions. Similar statements can be found elsewhere (eg 3-9). However, the explicit criterion for effusion is omitted from some textbooks (eg 10,11), which may partly explain the confusion (3,4) between diffusion and effusion.

The confusion is further compounded as diffusion rates are approximated (3,4,12-14) by Graham’s law of effusion (15):

\[
\frac{\text{rate}(1)}{\text{rate}(2)} = \sqrt{\frac{m_2}{m_1}}
\]

where the rates of effusion (or diffusion) for two substances (1) and (2) are inversely proportional to the square root of their molecular masses, \(m_1\) and \(m_2\), respectively.

Only gases satisfy the requirement of a mean free path that is large compared to the hole diameter (3,4). The reason is simple. In a liquid, the mean free path is much smaller than a molecular diameter because molecules are in close contact with neighbours (3,4). Hence liquid-phase effusion is impossible.

In the demonstration presented by Petrussevski et al., the solutions are unstirred and pass through a porous barrier (1). A variant experiment, in which the solutions are stirred, is the basis of the diaphragm cell, a standard method for the determination of diffusion coefficients (16).

Petrussevski et al. have presented an interesting demonstration (1). However, it must be correctly re-interpreted as relating primarily to the diffusion phenomenon.

The author thanks Jeanne Lee (李静宁) for helpful and encouraging discussions.

References
2. Chang, R., Physical Chemistry for the Chemical and Biological Sciences; University Science Books: Sausalito (CA), 2000.
12. Graham, T., Philosophical Magazine 1833, 2, 175.

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Authors’ response:
We sincerely thank K. F. Lim for pointing to certain issues in our manuscript [1] that were believed to be inconsistent/imprecise. The attempt to clarify imprecise statements is always welcomed and is of utmost importance for educational journals. In this reply we shall try to explain our motives for calling the process in question ‘effusion in liquids’. Let us first say that sometimes a statement can be considered as correct or wrong, depending on the definitions adopted previously. Speaking about effusion there are many different definitions (K. F. Lim has already identified this might-be problem). One definition is very precise [2–5]. We shall call this definition the strict definition. Here is an example [5]: … effusion is the process where individual particles flow through a hole so tiny they must go one at a time. In this condition the diameter of the hole should be considerably smaller than the mean free path of the particles. Gases effuse, the rate at which they do so is dependent on their molecular weight. Gases composed of particles with a lower molecular weight will effuse more quickly than gases composed of particles with a higher molecular weight… Others [6–10] are less precise, and will be called relaxed definitions. An example might be the following [6]: … molecules escaping from a hole in a container, a process known as effusion…

More sources for the strict definition can be found in K.
F. Lim’s letter. Let us also mention that many authors consider the effusion process as being exclusively a gas-phase property (something that could be criticized, as will be elaborated shortly).

If the relaxed definition is adopted as the working one (as was done in [1]), then from a formal point of view there is no contradiction in [1], as in the relaxed definition there is no mention of the mean-free-path as a criterion for effusion. One may, correspondingly, safely use the phrase ‘effusion in liquids’.

If effusion is understood as hindered diffusion through porous barrier (as was implied in [11]) then, again, there is no problem in calling the process in question ‘effusion of liquids’.

Irrespectively of the above, we feel that it would be honest to admit that the relaxed definitions are not necessarily correct. In the light of the strict definition, it indeed seems that the process cannot be due to liquid effusion and should result from diffusion. While this might be true, we would still say that one should stress the importance of the porous barrier. In that case, at the very least, the process would result from a hindered diffusion of the liquids through the porous barrier (no free diffusion could lead to an increase of the level of glycerol in the cup).

Finally, considering one of the statements of K. F. Lim that ‘Hence, liquid effusion is impossible’, we would like to say that in the light of the arguments based on calculations done by Mohazzabi and Cumaranatunge [12], this seems to be a somewhat peremptory assertion and may turn not to be a correct one. So far, Ref. [12] is the only one that explicitly states that effusion is possible in extremely dense systems (including liquids!). To the best of our knowledge, up to now nobody has shown that the conclusions of Mohazzabi and Cumaranatunge [12] are wrong. The authors discuss the feasibility of effusion despite the high frequency of collisions and the very strong intermolecular interactions that may even lead to significant deviations from Maxwellian distribution. The law, they conclude, still holds!

Let us put this clearly: we are in no way saying that Ref. [12] is a proof that what we demonstrate is a result of effusion in liquids. Indeed, it may be due to hindered diffusion through the porous barrier. We do believe, however, that the very existence of effusion in liquids cannot be precluded, unless sound arguments are given indicating what is wrong with the calculations (and correspondingly, with the conclusions drawn from them) performed by Mohazzabi and Cumaranatunge [12]. Consequently, it is possible that liquid effusion is at the origin of the effect that we present, no matter how unlikely it may seem at first sight.

Curiously, we could not find a recommended definition of effusion in the IUPAC Compendium of Chemical Terminology [13].

References

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An invitation

The editors invite readers to make contributions to this Journal. As well as papers submitted for peer review, we welcome any of the following:

• Short papers on chemistry topics or concepts, from an educational perspective
• Reflective papers teaching and learning chemistry – general or specific
• Letters to the editor
• Announcements
• Forthcoming events
• Books to review
• News about people or places
From APCELL to ACELL and Beyond – Expanding a Multi-Institution Project for Laboratory-Based Teaching and Learning

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Abstract

The Advancing Chemistry by Enhancing Learning in the Laboratory (ACELL) project is a well-established, multi-institution, collaborative project contributing to improvements in the quality of laboratory-based teaching and learning. ACELL is an expansion of the previous APCELL project and now encompasses all areas of undergraduate chemistry. It contributes to quality improvement in laboratory learning directly by providing a database of educationally sound, peer-reviewed, and student-tested undergraduate laboratory experiments. Testing of experiments is generally carried out at dedicated workshops, such as the one held in Sydney in February 2006, at which 33 experiments from 27 different universities from Australia and New Zealand were evaluated. In addition, by contributing to the professional development of chemistry academic staff by expanding their understanding of issues surrounding student learning, by fostering the development of a community of pedagogically aware educators, and by providing tools for analysing and documenting teaching experiments, the ACELL project has the potential to catalyse the improvement of experiments not directly reviewed by the project. This paper reviews the evolution of ACELL, its current position, and provides some suggestions for future developments.

I. Introduction

Chemistry is considered the central science because its core concepts are essential for almost every area of science, and it finds applications in areas including engineering, materials, industry, medicine, and mining. Laboratory activities are an integral part of chemistry education and according to the Royal Australian Chemical Institute (RACI) report The Future of Chemistry Study: Supply and Demand of Chemists\textsuperscript{1}, students of chemistry spend almost 50% of their time in the laboratory. The Advancing Chemistry by Enhancing Learning in the Laboratory (ACELL) project\textsuperscript{2} provides a database of educationally and chemically sound, peer-reviewed, and student-tested undergraduate laboratory experiments, a community of pedagogically aware educators, and tools for analysing and documenting teaching experiments. Furthermore, there is an emphasis on providing evidence of the effectiveness of the experiments as teaching and learning tools.

Students often indicate a preference for experiential learning methods.\textsuperscript{3,4} Within the Chemistry curriculum, experiential learning is predominately found in the laboratory practical context. Some of the aims of laboratory-based teaching and learning are to:\textsuperscript{5,6}

- encourage accurate observations and careful recording;
- promote scientific methods of thought;
- develop manipulative skills such as appropriate handling of glassware and equipment;
- give training in problem solving;
- elucidate theoretical work to aid comprehension;
- verify facts and principles already taught;
- be an integral part of the process of finding facts by investigating and arriving at principles;
- arouse and maintain interest in the subject; and
- make phenomena more concrete through actual experience.

This list may be aligned with the development of generic skills and graduate attributes that are critical for the success of university graduates.\textsuperscript{7} Laboratory-based learning is an ideal vehicle for developing graduate attributes, for instance, professional skills (critical thinking, problem solving, etc.), communication skills (written, oral, presentation), data handling (acquisitional, numerical, statistical), information technology skills (data manipulation and presentation, report creation, research), self-management (time management, planning, reflection and self-awareness), and interpersonal skills (teamwork, leadership, etc.). In short, the teaching laboratory has the potential to provide a comprehensive educational experience, touching on all aspects of the modern university teaching and learning paradigm.

It is well-recognised that effective learning requires learners to engage with the activities in which they are involved, and that such engagement has behavioural, cognitive, and motivational aspects. Behavioural engagement is facilitated in a laboratory setting as activities are hands on. However, research\textsuperscript{8} shows that little effective learning results unless students also engage cognitively with the activity, and there is evidence\textsuperscript{9} that the design of some laboratory activities does not facilitate high-level cognitive engagement. One way in which educators can try to foster higher levels of cognitive
Aims of ACELL
ACELL covers all areas and levels of undergraduate chemistry. As summarised in the introduction, the project has a strong emphasis on educational theory and practice, in particular, its application to providing evidence of the educational value of the experiments. Another area that has become more sharply focussed as the project has evolved from its earliest incarnation is the development of a community of interest10 in chemistry education within the broader academic community of the Australasian region and the provision of opportunities for professional development within that community.

The ACELL project has three core aims:

• to provide undergraduate chemistry experiments which are educationally sound and which have been evaluated by both students and academic staff;
• to provide opportunities for the professional development of chemistry academic staff by providing guidance and tools for the exploration of enhanced laboratory-based teaching and learning; and,
• to facilitate the development of a community of practice in chemistry education within the broader academic community of the Australasian region.

The first aim is, on the surface, a very utilitarian one. ACELL provides a single place, the ACELL website2, from which a complete, ready to implement experiment can be acquired. It provides a package containing everything needed to introduce the experiment into a unit or course, from student notes to technical and demonstrator guides. At this level ACELL provides a useful service to the chemistry education community, providing information that is typically not available from other sources of undergraduate teaching experiments. In addition, ACELL aims to add value to existing or new experiments by providing the pedagogical analysis through an Educational Template, which provides the adopter with effective guidance on integrating the experiment into the educational objectives of a unit or course. The Template not only provides the learning outcomes, but also evaluation data relating to the educational value of the experiment. Furthermore, it is the principal tool used in achieving the second aim. Most chemists engaged in teaching are not particularly well read in education literature, and are not conversant with the language and methodologies of that discipline. The Template engages teaching chemists into thinking about their laboratory-based teaching and learning activities,22 and at the same time provides an accessible entry point into educational concepts. Beyond the Template itself, access to educational theory literature has been offered by the provision of further explanatory material11 via the project website.

The purpose of this paper is to make a report on the progress of ACELL towards the objectives above. To this end, we will report on the first ACELL workshop, the launch of the new website, and discuss some of the future objectives, including an updated Template and future ACELL workshops.

The Origin of ACELL
To give ACELL a context, it is valuable to review the history of the project. The ACELL project has grown out of the Australian Physical Chemistry Enhanced Laboratory Learning (APCELL) project. This physical chemistry predecessor of ACELL has been previously described both in This Journal23 and elsewhere24,25 but as many of its key features are carried through to ACELL, it is worth discussing them here.

During the years leading up to the official start of APCELL in January 2000, discussions were held amongst a group of academics, which often included anecdotal evidence cataloguing the decrease in the number of students who were finding their physical chemistry laboratory courses interesting and which provided them with little or no motivation for their studies. These informal discussions drew attention to the widespread belief amongst academics that students studying physical chemistry were not learning in the laboratory as well as they should or could.

APCELL aimed to address this issue by producing a database of quality physical chemistry experiments, drawn from the existing experiments operating at the 30 universities represented in the wider APCELL team. In
an attempt to bridge the gap between relevant educational research and practising educators, an Educational Template\textsuperscript{23} was developed, which was an instrument designed to support reflection on the aims and objectives of the practical and the methods of achieving them, including providing information on how the experiment might achieve the affective aims outlined above. The educational research that underpins the Template and laboratory-based learning in particular has been described previously.\textsuperscript{23} At its centre was the learning outcomes matrix, in which the educator documents the expected learning outcomes, the way in which they may be achieved by the student, and the way in which both the teacher and the learner recognise that the outcomes have been achieved.

One of the most important outcomes of the project was an increased awareness of the importance of understanding and documenting the pedagogy underpinning laboratory teaching activities. In many cases teaching experiments have been in use for a long time, and often developed by a previous generation of teachers. Other than superficial acknowledgement of some aims, e.g., “practise performing titrations” or “demonstrate the concept of first order kinetics”, little thought is usually given to the deeper and wider learning outcomes possible and desirable for the experiments.

The main activity that fostered this awareness was a series of workshops run directly by the APCELL team or under the auspices of the RACI Chemical Education or Physical Chemistry Division conferences. The largest of these was the workshop held at the University of Sydney in February 2001. During the workshop both educators and undergraduate students participated as learners and both contributed ‘learner’ evaluation feedback. Many academics found that their conceptions of student approaches to experiments were challenged by the experience of working with, and as, students. Similarly, student participants found that their ideas of the philosophy and implementation of teaching experiments were open to question. It is not an overstatement to say that the workshop was a key juncture in the project and that both staff and students, some of whom came with a certain degree of scepticism, went away with an enhanced level of enthusiasm for the project. Further details on the outcome of this workshop may be found in the earlier paper in This Journal.\textsuperscript{23}

While specifically intended to address perceived problems in the Physical Chemistry curriculum, it soon become apparent that there was a strong desire amongst those exposed to APCELL to apply its methods and philosophy to the wider chemistry community. As one of the participants of the first workshop stated “What has to be done now is that you have to bring it to other areas (inorganic, organic, etc) so that you don’t have just good phys. chem. pracs but good chemistry pracs”. Another participant wrote that this project “should go far and improve laboratory work throughout Science”. Once back at their home institutions, many of the participants found that their colleagues were interested in applying APCELL to their own courses, outside of those recognised as being Physical Chemistry.

The Journey from APCELL to ACELL

APCELL was started by four researchers with an interest and motivation in improving laboratory teaching and learning in a single discipline: physical chemistry. By many objective indicators this project was successful – good experiments in physical chemistry were shared between universities, the workshops continued beyond the extent of initial government funding, via RACI conferences, several educational papers reported on the outcomes of the research, and an enduring community of physical chemistry educators was formed. The pressure for an expansion of the scope of APCELL continued to grow over the lifetime of the project. The four original APCELL directors therefore decided in 2004 to explore the possibilities and pitfalls of such a path.

i) During the initial four years, the APCELL team learned several important lessons, including that the activity in APCELL, though continuous from 2000 to 2004, was nonetheless diminishing in intensity over this time. This was clearly attributed to the exhaustion of the original funding, and in particular to the loss of a staff member to manage the day-to-day project activities. The management of APCELL in the later two years was left to the “spare time” of the directors, with the subsequent and inevitable result that, although the project continued, innovation and expansion was stifled. If APCELL was to be expanded in scope, a significant new injection of funds would be required.

ii) The APCELL team had developed a considerable understanding of physical chemistry laboratory learning – a subject that was well aligned with the discipline expertise of the directors. The team believed that discipline expertise would need to be extended to cover the breadth of the new expanded scope.

iii) One of the outcomes of APCELL was the Educational Template that served as a bridge between educational research and its practical implementation in a physical chemistry teaching laboratory. Was the template sufficiently robust to be useful in a broader context?

iv) The APCELL workshops were the keystone of the project. All experiments on the APCELL database had to be tested in a third-party laboratory and these workshops had proven to be an economical and reliable method for such testing. Physical chemistry experiments might use esoteric equipment, however other aspects more relevant to, say, a synthetic organic laboratory, such as transporting esoteric chemicals, and issues of chemical safety were not as fully explored as would be needed. The APCELL workshops were also attended by a more focussed client base. Would the APCELL - type workshop concept transfer across to broader interest base, and to a different set of logistical issues?
In 2004, the broader title of “Australasian Chemistry Enhanced Laboratory Learning” or “ACELL” was adopted. The new title reflected the expansion in scope to all aspects of chemistry, formal recognition of contributions made by New Zealand chemists in the past (including hosting one APCELL workshop), and indeed the desire to interact more strongly with the chemistry educators in the Asia-Pacific region. At this time, three new directors – Bob Bucat, Geoff Crisp, and Adrian George – were invited to join the management team, each of whom had established expertise in chemistry education. This expansion of the management team also broadened the range of chemistry sub-discipline expertise beyond that of the original team, which was desirable in light of the expansion of the project to all areas of undergraduate chemistry.

Funding for the expanded project was sought in 2004, and granted in 2005 through the Higher Education Innovation Programme (Department of Education, Science and Training). The grant provided funds to support an Associate Director to manage the day-to-day activities of the project, and funds for the inaugural ACELL workshop. Mr Justin Read, a PhD candidate with research expertise in Chemistry Education, and with degrees in both Chemistry and Educational Psychology, joined ACELL in 2005 as Associate Director.

The ACELL Workshop – University of Sydney, February 2006

All three objectives of ACELL coalesce at the workshops. It is here that the community of practice is fostered, that discussions of practical educational theory take place, and pragmatically, where potential ACELL experiments are first tested in a third-party laboratory. These workshops provide fertile interaction between teaching academics and undergraduate students, immediate feedback on the experiment from both teacher and learner points of view, and a rare opportunity to take teachers out of their “comfort zone” and into the realm of being an undergraduate laboratory learner again.

The first ACELL workshop was held at the University of Sydney in February 2006. At this workshop, 33 experiments from 27 different Australian and New Zealand universities were submitted for evaluation. Testing of the experiments was completed over a three day period by a team of 33 academic staff and 31 students from those universities, plus the Directors and the Associate Director. Appendix 1 lists the participants in this workshop, and shows that the representation covered a wide variety of institutions and chemistry sub-disciplines.

The structure of each day of the ACELL workshop is illustrated schematically by the cycle of photographs in Figure 1. Each day involved early morning discussion sessions focussing on a particular educational theme, with mid-morning and early-afternoon laboratory sessions, each of three hours duration and separated by a communal lunch break. In these laboratory sessions, participants took on the student role in testing experiments, with the exception that each academic who had submitted an experiment spent one day demonstrating that experiment. Participants were assigned to work with different people in each laboratory session, fostering networking opportunities for the participants as well as furthering ACELL’s community of practice aims. In many cases, and deliberately so, participants were forced to move beyond their comfort zone by undertaking some experiments in areas outside their fields of specific chemistry expertise.

This applied primarily to the academic participants as for most students all experiments are outside their comfort zone to a greater or lesser extent. It is fair to say that many highly competent research-active academics expressed no small degree of trepidation at exercising skills that they may not have used since they were themselves undergraduates. Figure 2 shows some of the directors of ACELL outside of their comfort zone! Upon questioning, the academics commented that by doing these experiments they realised that they had forgotten what it was like to be a student and that this made it difficult for them to judge the quality and effectiveness of their own experiments from the student perspective.
An integral part of the workshop testing process involves taking participants out of their comfort zone by working in unfamiliar areas. Amongst the directors, Simon Barrie (top left), who is not a chemist, tested a first year experiment, Bob Bucat (top right), a physical chemist, trialled an experiment in advanced inorganic chemistry, Geoff Crisp (bottom left) re-entered the lab for the first time in quite some while, Adrian George (bottom middle), an organic chemist, tried his hand at a laser experiment, whilst Scott Kable (bottom right), a spectroscopist, is shown doing wet chemistry in an analytical experiment.

An important part of each day was the off-campus debrief and discussion session (see Figure 1). Before the experience of the day’s activities was lost, participants were asked to critically evaluate the experiments they undertook that day in both a discussion forum with the submitter, (with notes taken), and anonymously via a written survey. These discussions often continued over dinner.

Substantial efforts were made to collect research data during the workshop. Participants were asked to complete surveys focussing on each experiment they tested, along with its associated Educational Template, and which (together with the discussions at the debrief sessions) provided feedback on each experiment to its submitter. In addition, a survey was conducted at the end which focussed on participants’ experiences of the workshop itself, its processes, and its strengths and weaknesses. Each of these surveys was designed to provide a mix of hard (quantitative), medium (coded qualitative) and soft (verbatim comment, examples are given below) data, allowing a deeper understanding to be achieved.26 Finally, some in-depth interviews with delegates have been completed, and more are planned for the future.

The survey data are still being interpreted, and the in-depth analysis of these data will be the subject of a later report. However, we can report on some of the preliminary overall results associated with the final survey. In brief, these data showed the positive contribution of the workshop to improving student learning and professional development. This development was facilitated by both the insight gained through delegate interactions and the improvement in understanding and awareness of educational issues. Figure 3 shows the overall very positive responses to three of the broad statements on the final survey:

- “The ACELL workshop offers a useful means to improve students’ learning in laboratory exercises”;
- “Participating in the ACELL workshop has increased my understanding of educational issues”;
- “Participation in the ACELL workshop has been a valuable experience for me”.

The Likert data were supported strongly by the freeform comments from both academics and students. Typical comments about the most valuable aspect of the ACELL workshop reveal:

- Staff: “Networking – I got to meet loads of new people. Hopefully I will be in contact with them in future.”
- Student: “To enable discussions between staff and students increasing the input towards improving laboratory learning.”
• Staff: “It made me sit down and think carefully about what I wanted my students to get out of my experiment, and how I could judge if they had been successful.”
• Student: “Staff and students working together and realising that setting up and performing a practical is not the easiest of things.”
• Staff: “Educational issues – as a scientist, I feel lacking in educational knowledge.”
• Student: “ACELL was such a great experience! I have met some amazing people, quirky people, and fascinating people … makes you realise that there really are people out there with the same interests. I am very honoured to have been part of a group that can make such a profound change to the chemistry curriculum in Australia / NZ. Cheers for the opportunity! :)”

The first two statements in the Likert data (Figure 3), along with subjective comments such as related above, highlight the powerful nature of the workshop in terms of achieving two of the specific aims of ACELL: to provide students with both a motivating and educationally valid learning experience, and to provide professional development for chemistry educators. Both aspects are essential components in improving the quality of undergraduate laboratory learning experiences.

Achievement of the third ACELL aim, which is to develop a chemistry education community of practice, will take some years to verify. If the experiences from APCELL are any guide, then the RACI-hosted workshops will be a crucial part of maintaining the ACELL community that has been established. The third Likert data statement (Figure 3), suggests, however, that the workshop has provided a very strong contribution to the fostering of this community.

The complete set of responses to both the Likert-scale and the open-response items are available from the ACELL website.

The ACELL website
The first, practical aim of ACELL is to establish a database of educationally validated undergraduate laboratory exercises. Of course, such a database has little value unless it is readily available to the broader chemistry education community. To this end, a specific stated outcome of ACELL in the original grant application was to develop a website for the dissemination of these exercises. This website has been launched with the URL: http://acell.chem.usyd.edu.au. The website already hosts all laboratory exercises previously validated under the APCELL protocol. A number of the “under review” ACELL experiments are also available.

The website has also been designed to foster the other aims of ACELL, particularly the education of practicing chemistry educators with some relevant aspects of education theory. To this end, the website provides copies of all ACELL publications as pdf files (with thanks to the copyright owners), and a number of unpublished articles written by ACELL (primarily JRR), on aspects of education theory. The ACELL website also serves to distribute the complete set of surveys concerning the ACELL workshop, including the overall survey that we reported briefly here.

The next two ACELL workshops are in the planning stage. The website is already advertising a half-day workshop being held as a satellite meeting to the upcoming Organic and Physical Chemistry conference (OPC07), to be held in Adelaide in February, 2007. Another workshop is planned in conjunction with the RACI Division of Chemical Education conference in Auckland, NZ in July 2007. The website will provide regular updates about these events.

ACELL and Beyond
Some readers may have noticed that while the “ACELL” acronym has remained, the formal title of the project has recently changed. Instead of “Australasian Chemistry Enhanced Laboratory Learning” as was used at the workshop described herein, the project is now called “Advancing Chemistry by Enhancing Learning in the Laboratory”. This change is prompted by a change of emphasis towards enhancing the learning, rather than the laboratory, and represents a new frontier for the project, which is to engage with the international chemistry community, for which “Australasian” is clearly inappropriate. We hope that workshop model and the ACELL process overall, both described above, can be successfully applied internationally.

There is nothing in principle to prevent the ACELL approach being applied in other disciplines such as biology, physics, or engineering. The potential for expansion to other domains is presently being explored at the University of Adelaide, where a pilot program is being run using the ACELL approach to evaluate experiments in immunology. The website provides the tools needed for similar trials to be run in other domains, and the ACELL management team would be happy to provide assistance for such trials.

Conclusions
The ACELL model has shown itself to be effective at engaging academic staff and students in a collaborative exercise. The workshop approach allows discussion of both pedagogy and discipline content, it engages staff in a scholarly approach to curriculum development, and provides a practical way for student feedback to be used in designing resource intensive activities. The applicability of the ACELL approach to other domains is presently being explored. The community of practice network established at the workshop continues to collaborate, whilst the materials provided on the ACELL website provide ongoing professional development.

Acknowledgements
The ACELL project would not be possible without the financial support of the Australian Government, through the Higher Education Innovation Programme. The School of Chemistry at the University of Sydney and the School of Chemistry and Physics at the University of Adelaide continue to provide staff and resource support.
to the project. Collection of data for this project was authorised by the Human Research Ethics Committee at the University of Sydney, project number 12-2005/2/8807. We acknowledge the permission of copyright holders to allow us to provide copies of publications on the ACELL website. Finally, we gratefully acknowledge the contributions of all academics, technical staff and particularly the students, without whom the ACELL project could not succeed.

References


(2) ACELL, The Advancing Chemistry by Enhancing Learning in the Laboratory Project. 


Appendix 1: ACELL Workshop Participants.
Staff and student participants of the ACELL Sydney Workshop, together with institutional affiliations.

ACELL Management Team
Simon Barrie, The University of Sydney
Bob Bacic, The University of Western Australia
Mark Buntine, The University of Adelaide
Geoff Crisp, The University of Adelaide
Adrian George, The University of Sydney
Ian Jamie, Macquarie University
Scott Kable, The University of Sydney
Justin Read, The University of Adelaide

Staff Delegates to the Workshop
Russell Barrow, Australian National University
Dan Bedgood, Charles Sturt University
Stephen Best, The University of Melbourne
Mary Boyce, Edith Cowan University
Judy Brittain, The University of Auckland
Michael Crisp, Flinders University
Murray Davies, James Cook University
Corry Decker, The University of Waikato
Michael Edmonds, Christchurch Polytechnic Institute of Technology
Todd Houston, Griffith University
Sid Howard, The University of South Australia
John Kalman, University of Technology, Sydney
Alesdair Lee, Curtin University of Technology
Peter Lye, The University of New England
Greg Metha, The University of Adelaide
Jonathan Morris, The University of Adelaide
Maree Nelson, Macquarie University
Janice Petherick, The University of Sydney
Andrew Pratt, University of Canterbury
Stephen Ralph, University of Wollongong
Vinita Ramkrishna, Charles Darwin University
Trevor Rook, RMIT University
Brian Salter-Duke, Monash University
Siegbert Schmid, The University of Sydney
Scott Stewart, The University of Western Australia
Rintesh Syna, The University of Sydney
Paul Thomas, University of Technology, Sydney
Susan Turland, Monash University
Tania van den Ancker, University of Southern Queensland
Eric Waclawiw, Queensland University of Technology
Magda Wajrak, Edith Cowan University
Paul Wornell, University of Western Sydney
David Weatherburn, Victoria University of Wellington

Student Delegates to the Workshop
Mark Agostino, Monash University
Peter Balding, Edith Cowan University
Sugandha Bhargava, The University of Melbourne
Anna Bradley, Victoria University of Wellington
Sebastian Bunney, Curtin University of Technology
Jessica Chadbourne, The University of Sydney
Kim Cheng, Charles Darwin University
Gan Yin Chin, The University of South Australia
Connie Chong, Monash University
Jo-Anne Creek, James Cook University
Ivo Dimitrov, The University of Auckland
Alan Downward, University of Canterbury
Matthew Griffith, University of Wollongong
Juliette Hamilton, Christchurch Polytechnic Institute of Technology
Allayna Holt, University of Technology, Sydney
Eric Lindberg, Griffith University
Martina Marinkovic, The University of Adelaide
Richard Milgate, RMIT University
John Naumann, The University of Adelaide
Sara Palmer, Queensland University of Technology
David Pham, University of Technology, Sydney
Heath Pilling, Flinders University
Jaucy Poldy, Australian National University
Lucynda Ryan, University of Southern Queensland
Annette Siddle, University of Technology, Sydney
Jason Smith, Macquarie University
Andrew Wallace, The University of New England
Sally Wishart, The University of Waikato
Alexandra Yeung, The University of Sydney
Aya Yuszman, The University of Western Australia
Mengfei Zhang, The University of South Australia

Technical Staff Support
Bruce Deliti, The University of Sydney
Anna Oprysa, The University of Sydney
Peter Roberts, The University of Adelaide

Thermodynamics of the \( \text{NO}_2 - \text{N}_2\text{O}_4 \) Equilibrium by FTIR: An APCELL Experiment*

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Department of Chemistry, University of Wollongong, Wollongong Australia, wprice@uow.edu.au

Introduction

An understanding of how experimental variables influence the position of equilibrium for a reaction mixture is of fundamental importance to a chemist, biochemist or other molecular scientist. The ability to describe a reaction in terms of its thermodynamic equilibrium constant and hence Gibb’s Free Energy and see the relative influences of enthalpic and entropic drivers gives a great deal of information about the processes in the chemical reaction. In addition, these parameters provide the basis for predictive tools to describe how the reaction will proceed under any experimental conditions. For example, a knowledge of the reaction enthalpy enables the temperature dependence of the Free Energy (and K) to the determined through the Gibbs-Helmholtz Equation. Although, the equations and concepts underlying thermodynamics are introduced at first year undergraduate level, it is rare to be able to study the thermodynamics of a reaction in detail until subsequent years. This experiment beautifully illustrates the amount of useful information that can be gleaned about the temperature dependence of a reaction in a clear way while ensuring students get good data in a reasonable time frame (ie one lab session).

The equilibrium between \( \text{NO}_2 \) and \( \text{N}_2\text{O}_4 \) is a classic experiment investigated in a variety of ways, often just to illustrate the perturbation of equilibrium and Le Chatelier’s principle in a qualitative fashion. It has normally been studied by measuring pressure as a function of temperature or by UV-Vis spectroscopy. Indeed, one of the authors can remember at school (in less OH&S conscious and encumbered days than now) having Le Chatelier’s principle demonstrated via a gas syringe being squeezed and the colour changing as more \( \text{N}_2\text{O}_4 \) was formed.

The experiment presented here is novel in the sense that it uses FTIR spectroscopy to determine the composition of the mixture as a function of temperature. From the changing absorbances for each species the students clearly see how the equilibrium is shifting. The experimental set up has proven to be very robust. We currently use the experiment at second year level. Numerous extensions of the experiment are possible including practice at vacuum filling techniques and more in depth understanding of the spectroscopy side, if the experiment was to be run at a higher level.

The experiment is designed to reinforce to students the basic principles of equilibrium and thermodynamic concepts and related equations. The students obtain the spectra and calculate the corrected absorbance of peaks for \( \text{NO}_2 \) and \( \text{N}_2\text{O}_4 \) by using the software to correct for background and baseline absorbance. From the absorbances of the species as a function of temperature, they obtain the molar extinction coefficient for \( \text{N}_2\text{O}_4 \) given the value for \( \text{NO}_2 \). The students are then able to determine the concentration and pressure based equilibrium constants as a function of temperature. This exercise is also designed to give the students practice and experience at setting up spreadsheets. From the van’t Hoff isochore plot the value of K at 298.15 K is obtained and the standard reaction enthalpy (\( \Delta H^\circ \)), together with the uncertainty from the regression analysis. These two values then allow the determination of \( \Delta G^\circ \) and \( \Delta S^\circ \) together with their respective uncertainties. The experimental values are then compared with those calculated from literature enthalpies of formation and Third Law entropies for the species.

The determination of errors through regression analysis and combination of errors is a very useful exercise for the students, allowing them to quantitatively assess the validity of their results. The students are then able to discuss the precision and accuracy of their results as well as their significance in terms of the reaction equilibrium.

This is a new variation of a classic experiment that allows students to learn more about the thermodynamics of equilibrium and simple FTIR spectroscopic techniques.

Educational Template

Section 1 - Summary of the Experiment

1.1 Experiment Title

Thermodynamics of the \( \text{NO}_2 - \text{N}_2\text{O}_4 \) Equilibrium by FTIR

1.2 Description of the Experiment

This experiment investigates the thermodynamics of a simple equilibrium process, namely the dimerisation of \( \text{NO}_2 \) to \( \text{N}_2\text{O}_4 \) and is directly integrated with the lectures where the \( \text{NO}_2/\text{N}_2\text{O}_4 \) equilibrium is used as an example for the determination of thermodynamic parameters. It does so by measuring a portion of the infra-red spectrum as a function of temperature. The portion of the spectrum analysed allows the calculation of absorbances and hence concentration of the two species present in the mixture. This in turn enables calculation of the equilibrium constant K as a function of temperature. The temperature dependence of K allows determination of the enthalpy change for the process via the van’t Hoff isochore equation. Using this value and the standard Gibb’s free energy change for the reaction at 25°C (determined from interpolation of the results for K), the standard entropy may be estimated.

The aims of the experiment are to enable students to understand the basic relationships governing thermodynamic quantities in a practical context, and how these quantities might be evaluated experimentally. The determination of thermodynamic quantities such

* Full documentation can be found on the ACELL website: http://www.acell.chem.usyd.edu.au/homepage.cfm
as $K$ or $\Delta H^\circ$ is relevant to all science based students to deal with reactions and change. The choice of the particular equilibrium to be studied is based upon its simplicity. Despite the slightly hazardous nature of the $\text{NO}_2/\text{N}_2\text{O}_4$ mixture the experiment is simple to use and is an extremely effective learning tool in that the students can visualise clearly the changing concentrations of the species and hence equilibrium constant through the changing peak absorbances as a function of temperature. Other aims of the experiments are to introduce students to modern FTIR spectroscopic techniques and equipment and help improve their analysis and manipulation of data through the use of spreadsheet/graphing software. The ideas and skills learned by students in this experiment are generically useful to a wide range of areas. It shows clearly how changes in experimental conditions disturb equilibrium and how modern spectroscopic techniques may be used to monitor this. This is relevant to all science students, be they biological chemists or atmospheric spectroscopists.

1.3 Course Context and Students’ Required Knowledge and Skills

This experiment is current taught as part of a second year Physical Chemistry subject primarily for Chemistry and Medicinal Chemistry Majors. Consequently assumed knowledge is generally 100 Level Chemistry and a basic understanding of equilibrium and heats of reaction. Two major portions of this second year subject are thermodynamics and spectroscopy. The lecture component of the course introduces students to the Laws of thermodynamics, the relationships between the fundamental thermochemical quantities needed in this experiment. The lecture course also introduces vibrational and rotational spectra of diatomic molecules. This is useful for understanding the experimental method used to study the equilibrium process. Prior knowledge of FTIR is not necessary, but the experiment acts as a useful familiarisation of the technique and gives the students a basic understanding. Basic spreadsheeting and graphing skills are not formally taught as part of the course, however, a number of the practical experiences encourage the students to use and develop their skills in this area.

1.4 Time Required to Complete

Prior to Lab 1 hour
In Laboratory 2 - 3 hours
After Laboratory 3 hours

1.5 Acknowledgments

The $\text{NO}_2/\text{N}_2\text{O}_4$ equilibrium has long been a classic system to study. This has normally been carried out either by pressure measurement as a function of temperature. (e.g. G.P. Matthews, Experimental Physical Chemistry, OUP 1985. Expt. 3.3, p95) or by visible spectrophotometry (e.g. Findlay’s Practical physical chemistry, rev. B.P. Levitt, Longmans, London, 9th ed., 1973, p189). The use of FTIR as a means of quantifying the equilibrium process is a new one. The original experiment was designed by David Griffith at University of Wollongong. The current experiment is the latest version.

### Section 2 – Educational Analysis

<table>
<thead>
<tr>
<th>Learning Outcomes</th>
<th>Process</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What will students learn?</strong></td>
<td><strong>How will students learn it?</strong></td>
<td><strong>How will staff know students have learnt it?</strong></td>
</tr>
<tr>
<td><strong>How will students know they have learnt it?</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Theoretical and Conceptual Knowledge**

<table>
<thead>
<tr>
<th>The importance of temperature in changing equilibria</th>
<th>By observing the change in the spectra with temperature and carrying out the calculations.</th>
<th>The data of concentration versus Temperature and answering the questions in the text.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The importance of enthalpic and entropic contributions to an equilibrium process</td>
<td>Calculating the terms $\Delta H^\circ$ and $\Delta S^\circ$ from the experimental data.</td>
<td>Successfully carrying out the calculations to determine these quantities and answering questions in the text.</td>
</tr>
<tr>
<td>The relation between the temperature dependence of the equilibrium constant $K$ and enthalpy ($\Delta H^\circ$) via the Gibbs-Helmholtz equation.</td>
<td>Determination of $K$ from the concentrations of the species and the plot of $\ln K$ vs $1/T$ and reading the information provided in the practical notes.</td>
<td>Obtaining a graph of $\ln K$ vs $1/T$ and a value for $\Delta H^\circ$ from the slope.</td>
</tr>
<tr>
<td>Use of Hess’ Law and the equation $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$</td>
<td>Carrying out the comparison of the experimental data with literature values of $\Delta H^\circ_{(\text{formation})}$ and $S^\circ$ for the species concerned.</td>
<td>Good agreement between experimental and literature values.</td>
</tr>
</tbody>
</table>
Scientific and Practical Skills

<table>
<thead>
<tr>
<th>Familiarisation with operation of FTIR (and use of circulating water baths)</th>
<th>Reading the instructions provided and other lecture related notes and by carrying out the experiment.</th>
<th>Obtaining reasonable looking spectra by comparison to reference data on wall.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manipulation of spectral data using software.</td>
<td>Performing the manipulations and following instructions provided by the lab manual and the demonstrator.</td>
<td>Determining absorbances from spectra and printed output.</td>
</tr>
<tr>
<td>Quantitative appreciation of sources of error from experimental data.</td>
<td>In our laboratory the students have a computer laboratory session early in the course dedicated to data analysis (spreadsheeting, statistical analysis and graphing).</td>
<td>Spreadsheet output and determination of required derived quantities.</td>
</tr>
<tr>
<td>Quantitative appreciation of sources of error from experimental data.</td>
<td>By prior instruction (see 3) and carrying out data analysis.</td>
<td>Determination of uncertainty in derived thermodynamic quantities.</td>
</tr>
</tbody>
</table>

Generic Skills

<table>
<thead>
<tr>
<th>Develop ability to write reports.</th>
<th>By carrying out the exercise, general instruction in lab manual and advice from demonstrators.</th>
<th>By presentation of final report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observe and measure a set of variables and draw conclusions from it</td>
<td>see above</td>
<td>By conclusions in written report.</td>
</tr>
<tr>
<td>Ability to apply theory to an unfamiliar situation.</td>
<td>By carrying out the exercise and analysing the data.</td>
<td>Comparison of experimentally derived results with theoretical ones.</td>
</tr>
</tbody>
</table>

Section 3 - Student Learning Experience

3.1 Did this experiment help you to understand the theory and concepts of the topic? If so, how, or if not, why not?

- The lab. manual intro. doesn’t mean much prior to the lab. But by the end of it the equations and theories mean a lot more.
- Slightly
- Yes – covered several areas of the theory like ΔH, ΔG, ΔS and Kp/Kc – gave a practical insight into these concepts.
- Yes, you learn how to use experimental data to calculate certain values.
- It did relate to the theory but it was completed before the theory component was taught. When the topic was covered in lectures the relevance of the experiment was seen.
- Yes, the explanation of equipment and theory was moderate, therefore making the theory a little bit clearer.
- It would have except that the experiment was undertaken before the theory was learnt, yet once theory was taught the prac. was understood better.
- Yes – it illustrates what was going on.
- Not really. It was not easy to understand what was occurring in the apparatus.
- Yes! It helped not only do individual calculations but actually logically progress from temperature and absorbance through equilibrium concepts to ΔH and ΔG. This process is not usually followed in exam questions etc. Helped overall understanding.
- Researching for the discussion helped me understand thermodynamics.

3.2 How is this experiment relevant to you in terms of your interests and goals?

- It is hard to know for sure but I am doing medicinal chemistry and this didn’t seem relevant to that and it’s not something I’m interested in.
- Use of machines to understand equilibrium processes
- Use of FTIR spectroscopy. Using ΔH, ΔS and ΔG values/calculations (use these later on in degree).
- Demonstrated a computer-based technique to analyse a chemical reaction.
- Not really relevant, since a lot of the experiment involved clicking a mouse, there was no real interaction with the system.
- In helping with experimental technique/computer use. It was helpful for long-term skills needed.
- Thermodynamic equilibrium is a concept I’m certain I will run into often in my future.
- Not much.
- Not really relevant to my goals or interests other than passing this course ie. Useful for tying subject matter together but otherwise not interesting.
- Helped me to understand equilibrium
3.3 Did you find this experiment interesting? If so, what aspects of this experiment did you find of interesting? If not, why not?
- I liked using Excel to generate the curves so you can visualise what is happening.
- Interesting to note that things happen so intrinsically on a molecular scale!
- Yes – interesting because we got to use the FTIR spectrophotometer.
- I did not find it very interesting. The actual prac. was boring, but it did help understand the concepts and theory.
- Not really. A lot of time was spent sitting around.
- Not really, it involved too much waiting around for temperature changes.
- Too much sitting around waiting for experiment to happen.
- It was interesting to watch the data points change with temperature, but waiting in between trials was tiresome.
- Not interesting because it was not very hands-on.
- The concepts are interesting; but the prac. itself is too much sitting around waiting for temperature to change etc. Equilibrium dependence on temperature is interesting.
- The experimental part I would have found tedious had it not been for the machine being broken.

3.4 Can the experiment be completed comfortably in the allocated time? Is there time to reflect on the tasks while performing them?
- The experiment can be completed easily and you can think about it during the prac.
- Yes – prac completed in 2 of the 3hr time allocation. Sufficient time to reflect on task.
- Yes, plenty of time because all you have to do is change the temp. every 10 or so minutes and get a peak on the computer.
- Plenty of time to complete the experiment and reflect on the tasks.
- Yes, there was plenty of time to both complete the experiment and discuss concepts.
- Yes, there was sufficient time to reflect on the principle of the prac. as completing.
- Yes
- Yes it can. Yes, there is plenty of time to reflect while the temp. changes and the scanning is completed.

3.5 Does this experiment require teamwork and if so, in what way? Was this aspect of the experiment beneficial?
- Teamwork was not required to complete the prac.
- n/a
- Yes – required 1 person running computer/temp. thermostat and 1 to record data/do calculation. This teamwork aspect was beneficial as I got to work with/get to know another student.
- No. The aspect of the experiment was beneficial.
- Could be done individually.
- Not really, a single person would be able to run this experiment.
- Well there was a team yet one person could have completed this successfully.
- I did it alone and I was fine.
- No it doesn’t require much teamwork.
- didn’t really need teamwork – but it helped to talk about baseline positions etc. through the prac.
- The experiment appeared to require little skill to perform the tasks required.

3.6 Did you have the opportunity to take responsibility for your own learning, and to be active as learners?
- Yes – the themes in the intro of the manual can be looked up in texts and on the Web and IR is in other chem. classes so there is plenty of info on that.
- Yes – demonstrator went through the way the instrument works and gave us an opportunity to learn some of the theory behind the prac. And become an active learner.
- Yes, it was easy to ask a lot of questions and do relevant calculations within the time allocated, therefore becoming “active as learners”.
- Yes – had to understand (ie figure out) most components of all lecture material – ie work through it all to solve the problem.
- Yes – as the graphs were just given to us, all discussion was based on individual research.

3.7 Does this experiment provide for the possibility of a range of student abilities and interests? If so, how?
- Yes – you could have no background info or a lot and still be able to complete the experiment then research to do the questions. It was a good exercise for learning Excel esp. with the sample formulae given.
- Not really. Prac. was not interesting in itself physically and there weren’t many angles to look at in the prac.
- More focused on students studying physical chemistry.
- Not really. Results were all generated by the computer.
- Not really, it was a relatively slow and boring practical that didn’t provide an interest for many students.
- No – not much variety within the experiment.
- Yes – detail of response relies on understanding level; knowing formulae etc. will allow for completion – but thorough understanding > better answers

3.8 Did the laboratory notes, demonstrators’ guidance and any other resources help you in learning from this experiment? If so, how?
- The lab notes simplify/summarise the themes in the lectures and text books and put into the context of a real prac. The demonstrator was very helpful by explaining in English!
- Yes, it was clear but some mechanisms were tricky.
- Lab notes had a good theoretical intro and lecture notes supplemented the experiment.
- Yes, the lab notes told you how to do the calculations from experimental data.

*to be continued on page 23*
Evaluation of the application of a flexible delivery approach to first year chemistry students

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Abstract
This paper reports on the evaluation of the use and impact of a constructivist approach in an online learning environment. The context was the implementation of flexible delivery for first year chemistry students at Swinburne University during 2004. With the transition to tertiary education, involving varied and often unrealistic expectations of life at university, engaging these students presents continual challenges for teaching academics. The teaching employed in this approach used a mixture of both online and face-to-face delivery. Lectures were pre-recorded and delivered using video streaming via the Blackboard online learning management platform and CD ROM. Theoretical concepts and practical skills covered in the lectures were then reinforced in face-to-face tutorial classes and laboratory sessions. Online discussion forums were also established to encourage scientific discourse and help build a student-centred learning environment. One of the greatest challenges the teaching academic faced was the development of a range of delivery approaches for students who demonstrated different learning styles who entered with varying background knowledge. Evaluation of the targeted outcomes showed that issues such as social dynamics and staff inexperience had impacted the student learning experience more so than issues such as the diversity of learning backgrounds and the new technologies.

I. Instruction
Impact of Changing Student Requirements and Course Content
At Swinburne University of Technology, an Australian University, Chemistry is a subject taught to a group of students entering a variety of science streams. Biotechnology (in single or double degree formats with Business and Multimedia options) and Environmental Health Science students are required to study and pass the semester one, first year chemistry subject to satisfy prerequisite requirements for latter subjects in their respective courses. As a result, the students come into the subject with a wide range of chemistry backgrounds and experiences: VCE (Victorian Year 12 Certificate) level, middle school level only and mature learners returning to study after some time out of the education system. This raises difficulties in obtaining student engagement in the traditional chemistry theory and practical components and then maintaining interest, and to promote learning throughout the semester. To add to the difficulties in the teaching and engagement of such disparate chemistry backgrounds is the personal change and acclimatisation needed by these new students upon being introduced to a tertiary learning and social environment. A further factor is the larger distances that the students now travel on a daily basis to attend classes, timetabling issues with more complex streams of courses, differences in computer literacy and facilities and part-time job commitments resulting from increasing financial pressures.

Traditionally chemistry has been taught passively, with the teacher being more active than the student; delivery being via low interaction lectures, reinforcement through a laboratory component. With the repackaging of science courses so that the emphasis has shifted away from studying only one science stream, chemistry in this case, to now encompass fields such as biology, biochemistry and environmental science, the profile of students studying the chemistry component has changed. The change from an information-based approach to a constructivist approach was introduced to enable these students to have a greater input into their learning and interaction with the teaching academics. This increased the demands that students make and expectations they place on their tutors and lecturers. It is important that a balance is achieved between the students having input, with elements of self-direction and responsibility for their own learning, and students having varied opportunities for academic support and student-to-student communication. A shift away from teacher-centeredness to student-centeredness can enable flexibility in how the students become engaged with learning the material made available to them and also how they communicate and work with each other in an informal learning environment. As discussed by Redish, Saul and Steinberg (1998) the focus needs to move towards “what are the students learning and how we make sense of what they do”. To address these needs, a social constructivist approach was taken in developing and introducing some components to enable a more flexible approach in terms of delivery. A range of methods were made available to (a) gain the students’ interest, (b) enable them to question and discuss amongst themselves (c) apply these concepts and (d) give feedback to the academics guiding them through the semester. That being said, one of the main goals of the project was to produce a learning environment that would act to stimulate and facilitate discussions amongst students and their tutors. The suitability of adopting this approach for teaching science students was evaluated along with whether students commencing learning in a tertiary environment can act as, or transform into, active learners.

Opportunity for Review of Subject Delivery
The chemistry subject was chosen to trial the new technologies due to the delivery modes that were already being used to deliver the subject i.e. lectures, interactive
tutorials and laboratory sessions. In choosing this subject it also presented the opportunity for a review of the subject design. One consideration was the cost effectiveness of altering the delivery of the subject. It was desired that time and personnel resources were not to be extended any further, or more realistically only minimally, during the preparation, delivery and support phases. The mix of delivery modes already in place enabled a relatively low workload for adaptation of the subject material and integration of technologies such as discussion forums and quizzes into lesson plans and support material into the syllabus. It was anticipated that including these additional aspects may be of benefit in engaging more students and would encourage student attributes that can be difficult to quantify and include in science based courses eg verbal and written scientific communication abilities.

Goals of the Project
The primary aim was to introduce an element of social constructivism into the subject through the opportunity for active participation in the delivery and encourage learners to develop, compare and understand different perspectives or approaches. Situated learning theory was utilised along with constructivist philosophy (Wong 2004). Links in the curriculum were made between labs, tutorials and discussion opportunities, providing context and activities to the learning environment. The approach included provision of scaffolding in the construction of chemistry knowledge through support from tutors as well as peers. The frames of reference for the evaluation were the suitability of the approach, and of the chosen technologies, for the engagement students who had a wide range of prior learning and varying learning styles.

Instructional Design of the flexible delivery approach
Despite the differences between the objective and constructive approaches in designing the availability and function of the material, in practice it is usually a mix of the two. Davidson (1998) highlights that in practice circumstances surrounding the learning situation frequently dictate and aid in the decisions in terms of which learning approach is most appropriate. Importantly it is necessary to recognise that some learning environments require prescriptive solutions, and others, learner control of the environment.

For this subject, the roles played by the academics were, as it was traditionally, with tutor and lab responsibilities but with the introduction of additional interaction points. The traditional large lectures (70 – 80 students) were replaced by a video-lecture package obtained either by streamed video through the subject website (Blackboard) or from a resource CD. Asynchronous communication was introduced to stimulate student engagement and facilitate social interaction outside of the classroom. The lecturer, with tutor involvement, initiated the online discussion forums by posing a question or submitting a thought for each lecture topic to encourage weekly reflective and scientific discussion amongst virtual tutorial groups. In addition, further points of engagement were set up to facilitate and foster tutor-student communication: email contact, weekly feedback on assessment items using online lab results postings and practice maths skills quizzes. Muirhead (2000) found both students and teachers had to be active participants for the interactivity to be as effective as intended. It was expected that this aspect could significantly influence the experience of students, and also that of fellow academics. Effective communication between teacher and learner is essential and influential on the learning experience. Rowntree (1995) holds that an active academic collaboration is the vital integrating factor that helps learners to successfully negotiate the subject in question. It was recognised that the aim of fostering active rather than passive learning was likely to place additional demands on the teaching staff involved, and the extent of this aspect was evaluated.

Incorporation of New Technologies
The major change to the delivery and learning environment was the replacement of the face-to-face lectures with the video package. This was made possible through the availability of new technologies such as Producer (Microsoft). It enabled a package to be recorded and assembled that consisted of the lecturer presenting the lecture material via video, the Powerpoint (Microsoft) presentation embedded and displayed on the screen simultaneously and another window containing the main objective points enabling skipping or backtracking through the lecture video. This gave the opportunity for the students to take either a systematic or holistic approach to work through each video lecture according to their own learning style. Importantly it gave students with minimal prior chemistry knowledge, the option to view each lecture many times, pause the video to allow notes to be made on their copy of the lecture handouts, and to work through the sample problems given in the lecture with the lecturer. This could then be revisited again to allow them the opportunity to review the topic material. Other students with a sound knowledge of chemistry concepts from prior learning could skip through various topic objectives, or attempt the set problems separately and check the video presentation for confirmation. The intended advantage of this technology was, from an academic perspective, to assist students to develop attributes such as independent and self-directed learning, self-motivation and time management skills.

Another area that had been restricting an important aspect of flexible delivery for science subjects had been the availability of suitable software to enable problems with mathematical or symbol content to be explained out of the classroom. The purchase of MIMIO® by Swinburne enabled insertion of chemistry problems worked on a physical whiteboard to be converted to an electronic image and uploaded into the Blackboard site. It combined whiteboard notation with an audio explanation. This was an important addition to the effective use of the flexible learning aspect of the videoed lectures as in a face-to-face traditional lecture the whiteboard is frequently to further explain concepts that often take time to be picked up by the student e.g. balancing chemical equations, stoichiometric problems, acid-base and solubility equilibria and basic mathematical manipulations.
Model of the Integration of Technologies and Student-Tutor Interaction
The integration of these technologies into the approach was to provide varied avenues of engagement and a basis to introduce and encourage scientific discussion and sharing of experiences. It was to also provide an element of dialectical constructivism (Moshman, 1982) into the subject throughout the course of the delivery. This was to emphasise the negotiation between individual and social experiences or knowledge to facilitate learning as solely focussing on the individual construction of learning is inadequate. It was important to also include technology tools such as asynchronous communication to facilitate and prompt collaboration and sharing of experience (Scardamalia and Bereiter, 1996). The social interaction, moderated to varying degrees by a tutor or demonstrator was to enable a sharing of ideas, difficulties and learning approaches.

One of the foreseen hurdles to the successful take-up and acceptance of this model by the students was the lack of prerequisite skills of the students upon entering tertiary education, as raised by Taber (2000). This was an important factor in the students in that we were expecting the students to be able to use skills such as time-management, self-discipline, all characteristics exhibited by independent and adult learners. The majority of the students entering into the course were in fact transitional learners. They had only just begun to acquire such skills and had a significant adjustment to make whilst undergoing the transition into the university teaching and learning system. As a result, the tutorials were closely linked to the lecture material, which was emphasised at the beginning and end of each video presentation and short tutorial tests were introduced. Laboratory classes were integrated with the schedule for viewing topic lecture videos. This gave independence and flexibility in terms of covering theory components but also kept the flow of information succinct and continuous through the semester period.

In considering a constructivist instructional design model, such as that proposed by Jonassen (1999), design elements such as enabling multiple paths through the material, clear identification of the learning domain and provision of tools for a learner controlled path, were considered to be central to the design of the flexible delivery approach. A schematic of the subject is shown in Figure 1 that relates the important components of the flexible delivery package. It was desirable that whilst the delivery of the material was central, there be several avenues for communication and application of the learning in an authentic context (Reeves and Reeves, 1997). This was designed to occur through tutorials, lab sessions and discussion forums. The evaluation modes were used to obtain feedback for the inner circle components, i.e. communication, delivery and assessment, to enable adjustments to be considered and incorporated into the design of the delivery approach.

Figure 1:
Schematic of the Flexible Delivery approach taken, its components and the relationships between delivery, assessment, communication and evaluation for the chemistry subject
Formative Evaluation and Results

In evaluating the approach it was anticipated that the participating students would raise several concerns, ranging from their perception of the usefulness of the delivery package, lack of engagement, to difficulties with self-management and keeping to the schedule for the whole semester period. A survey was constructed and several focus groups sessions were conducted at the end of the delivery period to gain feedback from both students and the involved academics on these points. In addition data was sought relating to whether the technology and/or prior learning backgrounds were considerable contributors to any difficulties encountered during the course of the delivery period. As Salomon (2000) discussed, the use of technology can tend to be in terms of accessing information, rather that guiding the attainment of knowledge. This is an important distinction that needed to be evaluated for this project.

In this iteration of the flexible delivery model, the students group in total numbered 71, which was split into 3 tutorial classes of 22-28 students for the teaching period. All students were invited to participate in focus groups, two of which were formed consisting of 9 and 10 students. The academics involved were the 3 tutors and 1 lecturer. Interestingly each focus group (both academic and student groups) highlighted the main issues with the management and implementation of the flexible delivery approach not to be with the chosen technologies but with:

- Difficulties in determining a principal contact point with the absence of a physical lecturer.
- The impact of the psychosocial environment in tutorials.
- Insufficient orientation into the subject and flexible delivery approach.

Impact of the New Technologies – Social Dynamics

Underlying each of these issues were the major changes that the students were encountering upon entry to the university learning environment. Independence and responsibility for their own learning is a new concept to many students when they begin tertiary study. One academic involved in the tutorial component of the delivery found that the greatest disruption and influence on the learning environment and acceptance of the delivery mode was the psychosocial environment in the tutorial class. The class was observed to split, not according to learning styles or prior chemistry learning but according to social dynamics. Comments from the academic interviews were interesting for this particular group – (sic) “probably split it into four…1. straight out of high school, fairly quiet people, had a science background, all they were really getting used to was the new delivery system. 2. mature aged students, little bit of problem with chemistry but not much of a problem with the flexible, learning independently. 3. had trouble with understanding chemistry, wanted to have someone face to face, fairly shy, embarrassed, wanted to be able to do it anonymously and 4. your clowns, just couldn’t be bothered”. The final observation from the tutor was of the splitting into the above groups was not reflected in the marks, but a factor of social behaviour and consequential learning environment in the tutorial class.

The students’ learning environment in the classroom was greatly influenced by a disruptive social element that altered others perception of the learning environment and their confidence. This was also transferred to the virtual environment in the discussion forums set up. The composition of each of the online groups was a mirror of the classroom tutorial groups, and as a result the social dynamics were also present in the online contributions. Tally data from Blackboard showed that “lurking” (the student reads and follows online discussions but does not participate or contribute) far outweighed contributions. Initially this was thought to be due to the varied chemistry backgrounds; some students may be discouraged by concerns that fellow classmates would think their postings to be less intelligent. Rowntree (1995) observed the resultant tendency to be either more aggressive or to not contribute. However as Yeo (2004) discussed, social dynamics of a student group and how it influences motivation and learning behaviours can have just as much impact as the mode of delivery used or the subject material. Moallem (2001) also reported that students related how they were wary of contributing to the discussions due to lack in confidence and worries that their postings may not be deemed intelligent enough by their peers and would be saved for the duration of the subject. These students were more comfortable with gaining feedback from an instructor rather than from their peers.

Acceptance of the technology was not seen to be a significant issue. Troubleshooting facilities were made available and most of the problems were sorted out early in the semester through contact with the tutors or through online discussion forums that had technical support personnel moderating it. On the otherhand there was the underlying expectation that a subject, whether comprised of lectures, labs or tutorials, would be delivered by an academic for the published number of contact hours per week (a total of 6 hours consisting of 3 sessions of 2 hours each for lectures, tutorials and labs), rather than the offering of varied delivery modes. There was an associated reoccurring expression of dissatisfaction submitted through the anonymous student survey of perceived loss in value for fees (HECS) if the 2 hours allocated for lectures was not delivered in the traditional face-to-face by the lecturer.

Academic Commitment

The time spent on building and maintaining the online discursive resources varied from minimal contact (either office consultation or online) to almost daily basis. Tutors found this strongly corresponded to classroom observations of confidence of the student involved and their dependence on the tutor to initiate any discussions. This was especially so for the students who were having difficulty becoming self-directing in their study. Such interaction resulted in a greater than anticipated time
commitment from the tutors, which could not always be met satisfactorily. As Flottenmesch (2000) described, students tended to judge the quality of their experience by the level of interaction by the involved academic. Inexperience of the tutors in setting initial “rules of engagement” in terms of their own role in the online discussions also contributed to a greater time commitment – setting unrealistic response time expectations from the students of their tutor and the tutor not encouraging and enabling enough time for the students to communicate and set up discourse independently. This introduced another variable between tutorial groups. The inclusion of the online discussion groups was considered to be central to the successful implementation of the model. To successfully add an element of social constructivism, the groups needed a means to socially construct knowledge (Stacey, 1999). This became evident towards the end of the subject when the forums began to evolve into a valuable resource of knowledge, with discussion of various approaches to problem solving and communication evolving into a scientific context. Concurrently the tutors also developed a resource that could be used in further iterations of the subject that would enable a more efficient use of their time and discussion board materials.

Initial Analysis of the Effect on the Distribution of Grades
A trend analysis of grades obtained for the assessed components, whilst only for one year, showed no significant change as a result of implementing the flexible delivery model. It is not possible to draw firm conclusions, as academically student groups each year are quite variable, however it can be noted that the performance was relatively close to that of the previous delivery mode. The overall class average was slightly higher than the average calculated over the years 2002-2004, with 73% compared to 70.3%. In terms of the distribution of grades earned by the students, there appears to be a shift in the population for each category upon the implementation of the new delivery approach. One trend seen in Figure 2 is the shift of students away from the middle grades i.e. from a Pass towards the higher grades of Distinction and above in comparison to 2003.

Figure 2: Trend of the overall grades awarded to students completing the chemistry subject; B – borderline, P – pass, C – credit, D – distinction and HD – high distinction. Also shown is an adjustment for the discussion forum contribution mark that had not been part of the assessment scheme in 2002 and 2003.

The distribution was also very different to that seen for 2002. This could be linked to several contributing factors: difficulties faced by students in becoming more self-directed and responsible for their learning and the delivery being less teacher-learner centred. Given possible variables - such as exam composition, changing of tutor staff, intake mix of students for each course stream, the impact of inexperienced tutors on the learning environment and student engagement - no real conclusion can be drawn as to their contribution. The assessments items were constant except with the inclusion of the discussion contribution mark in 2004. The effect of removing this component was examined and the adjusted assessment scheme was recalculated and is also shown in Figure 2. It caused only a slight alteration in the proportion in all ranges, with no effect on the Pass range. More data analysis needs to be done and further groups need to pass through the subject before any further conclusions can be drawn on the impact on grades and assessment.

Impact of the Flexible Delivery Model and Conclusion
The flexible delivery model was shown to be successful from an implementation and application of technology viewpoint. It was required to engage a diverse body of students, with varied learning styles and chemistry backgrounds. Students with prior tertiary learning history or with confident and self-directing learning styles embraced and received the flexibility model very favourably; others required a more teacher-learner centred approach. This latter group of students gave feedback via surveys and focus groups that although teaching was supported by tutorials and lab sessions, they did not consider it to be sufficiently comprehensive for their learning needs, be it due to personal or social learning perceptions rather than academic outcome.

A successful transition into tertiary learning was a major influence on the students’ social interaction and learning experience. The psychosocial environment for one group of students impacted on the learning environment in the classroom and participation in communication avenues such as discussion forums. The academics, specifically the tutors involved, spent more time establishing and interacting with online tutorial groups than was anticipated.

Considering the above, additional support for the teaching staff in terms of managing online communications and tutorial psychosocial influences will be implemented. Improved orientation for students into the e-learning environment will also be incorporated.

In summary the project used a constructivist instructional design approach to develop and implement a chemistry subject to provide flexible learning opportunities via incorporated technologies. This enabled an element of social constructivism to be introduced into the subject through active participation in the delivery. It was shown to enable scaffolding in the construction of chemistry knowledge through support from tutors as well as peers.
A cyclic evaluation, review and development process will continue, with emphasis on the assessment scheme and further incorporation of situated learning theory to expand on the constructivist approach to learning and teaching.

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References


3.9 Are there any other features of this experiment that made it a particularly good or bad learning experience for you?

• Good – got to do calculations on $\Delta G$, $\Delta H$, $\Delta S$, $K_p$ and $K_c$
• No

3.10 What improvements could be made to this experiment?

3.11 Other Comments

• Prac gave accurate results to theoretical results – confidence building for calculations related.
• When this experiment was attempted, the IR machine was broken, so the experiment consisted of obtaining someone else’s results. I did not find that particularly beneficial.
Playing it safe?

Students’ study preferences in a flexible chemistry module

Kim McShane, Mary Peat and Anthony F. Masters

Abstract

There is a growing trend in higher education, especially science, to look at online delivery for all or part of a course, even in an on-campus situation. Partly this is because it is becoming more difficult to support student learning if the students are unable to attend all of the face-to-face opportunities. To promote independent study and to provide flexibility in an increasingly crowded student timetable, third-year students were offered the choice of undertaking a seven-week Chemistry module via on-campus face-to-face lectures, online only or by combining both modes. The student group was surveyed to determine the study options the students took up, and their reasons for those choices. Student feedback gathered in survey data and in follow-up interviews shows that this undergraduate cohort, enrolled in a traditional, research-focussed university, continued to expect face-to-face lectures as part of their university science studies. The popularity of the face-to-face lectures raises important questions about student readiness for online learning, particularly when the students have had limited exposure to online instruction in their previous undergraduate years. Students expressed a preference for the on-campus timetable structure as a way of organising their approaches to their study, fearing poor time management and procrastination if they took up the online-only option.

1. Instruction

Over the past ten years there has been a growing concern internationally about decreasing enrollments in the sciences and, in the more junior years, high withdrawal and failure rates. In Australia the closure of a number of Chemistry departments or their merger into hybrid schools is evidence of this decline. Additionally students are now taking longer to finish their degrees and are spending more of their time employed during teaching time to support themselves and their lifestyles. Universities are responding to this challenge by developing a range of strategies that are labelled collectively as ‘flexible learning’. Much of the public discussion about flexibility in higher education institutions centres on the notion of expanding student options, in terms of what, when, where and how students choose to learn. The integration of information and communication technologies (ICT) into teaching and learning and in particular, web-based (online) learning, is one recognised flexible learning strategy.

Web-based learning offers enhanced flexibility for students who work to support themselves. The skills required to manage and manipulate online information and communication are transferable to other contexts, and web resources and interactive online study can encourage independent, autonomous learning. Increasingly university lecturers are considering using the web to create new learning contexts to supplement and/or support traditional on-campus learning. Nowadays a university subject may comprise a mix of face-to-face and online learning environments, but are the students ready for this?

There is some evidence that the provision of more flexible learning opportunities can encourage meaningful, independent learning in the sciences. The offering to students of more flexible approaches to teaching and learning is also supported by the research on student learning in the higher education literature. A key finding of that research suggests that students who experience some independence and freedom in learning are more likely to adopt deeper approaches to study and have higher quality learning outcomes. By combining face-to-face and electronic options (mixed-mode teaching and learning) lecturers are able to offer to students a greater variety of learning modes and thus support an increase in their independence and freedom in learning.

This paper reports on the findings of a survey conducted with a cohort of students in Science in a research-focussed university. The students, who had enrolled in a third-year Chemistry module on lab safety, were offered some flexibility in how they would study: they could attend the on-campus lectures, access the online module materials, or combine both options so as to meet their needs and circumstances. They could elect to study the module in the first or second semester of the year. Given this flexibility, the initial research interest was on students’ learning preferences. Would these third-year undergraduate students select the more flexible online materials or would they choose to attend on-campus lectures? What were the reasons they gave for those preferences? How useful would they perceive it to be in supporting their learning? It is not easy to evaluate an innovation such as this. In this paper we report on the findings of a small study conducted with a cohort of students in Science in a research-focussed university. Rather than relying on one particular form of evaluation, this multi-method study drew upon several sources. These sources comprised syllabus information provided by the faculty member who taught the unit, demographic and evaluative electronic survey data, and detailed follow-up data. The next two sections present a description of the module and an outline of the research procedures, followed by the findings and some discussion of the implications of these for curriculum design and future research.
Description of the module
This compulsory module, comprising lectures and group work, but no wet laboratory practice, was introduced into the final semester of the final year of the degree program because it was understood that

- the students had studied enough chemistry to understand the chemistry involved;
- they were completing chemistry majors, and some of these students after graduating might need to take responsibility for safety in the early years of employment; and
- approximately half the third year class proceed to an Honours degree (and half of that group to a research postgraduate degree). The Honours degree is conducted almost entirely by research. Formal safety training in the semester before that degree was deemed to be an appropriate underpinning of the start of research training.

It was also acknowledged that a module in the third year program could be taken by new research staff and students as part of their induction program. Timetabling demands made it difficult for students to take the compulsory module and the chemistry of their choice, and this led to the development of an online version, available over the same period as offering them face-to-face. Thus students would be able to choose on a weekly basis, whether to attend the lectures or go online.

It was decided that the content of the module would emphasize a number of aspects including the legislative framework of safety and how to access this information (eg. from the various Australian Standards), an introduction to patents, and a mix of topics illustrating the chemical understanding of safety and of practical safety matters. The online version replicated the content of the face-to-face program.

The online version was delivered via the WebCT platform. The resources initially developed for students included the face-to-face lecture PowerPoint slides with separate downloadable text (this equates to the face-to-face lectures), hyperlinks to, for example, MSDS and patent sites, a library of digitized 35mm slides (that illustrate aspects of safety in the workplace), and email contact with the lecturer. The online materials represented seven face-to-face lectures but also included links to relevant online materials not easily demonstrated during face-to-face presentations. Subsequently, the illustrations and text were integrated in a single web document for each topic.

The assessment for the module was of two types, depending on the class size. Assessment for the larger class was a choice between an essay on a safety topic (e.g., “The safety of theatre fogs”), or a web-design exercise on MSDSs. Assessment for the smaller class consisted of a group assignment. Groups of up to five students researched a given topic, produced a poster and presented the poster to the rest of the class. Formative feedback was given to the students about their poster and presentation by the rest of the class, and summative assessment was the responsibility of the lecturer.

Methodology
An e-mail survey instrument (Appendix 1) was developed to gather information on student demographics, when they participated in the chemistry module, how they attended (face-to-face or online), and how useful they found the two delivery modes. Likert scale questions explored issues to do with the usefulness of the two delivery modes for supporting student learning, and open-ended questions allowed for expanded free-form responses to these issues.

The methodological focus of this small-scale research study was limited to exploring a particular educational phenomenon in context, with the expectation that this closer analysis would shed new light on familiar issues for future research. To develop this qualitative dimension of the study, the researchers conducted follow-up phone interviews with six of the e-mail survey respondents, and these conversations revealed relevant insights into the students’ choices for the learning modes in the module. Of the six interviewees, all of whom volunteered to be involved in a telephone interview, one student studied the module ‘mainly online’ (due to a timetable clash), two studied the module face-to-face by attending the lectures and collecting the hard copy notes and handouts, and three studied the module in combination, by accessing the online material and attending face-to-face lectures. That is, five of the six students attended some or all of the lectures. The discussion which followed was shaped in the first instance by the statistical data and the interpretation of this material was enhanced by the experiential insights of some of the students who studied the Chemistry module.

Findings
There was a 50% response (n = 31) to the e-mail survey from the total student cohort (n = 61). While this is in fact a very good response rate to an online evaluation questionnaire (13), any generalisation from the quantitative data only should be approached and read with caution.

The students who responded to the e-mail survey were representative of the demographic profile of the total cohort of students in the module. From those who responded to the e-mail survey, there was an equal split of 50% between the genders (compared with a split for the entire cohort of 45% female, 55% male). Mature-aged students comprised 30% of the total respondents and this was also the case for the entire cohort. In terms of previous use of online material, 83% of the sample reported accessing and using online materials (MSDS sheets, lecture and tutorial notes) in other programs of study before participating in this module. Most of the students (75%) had taken the module in first semester, as
The latter statement was traditional the semester in which the module has been offered (compared with 77% of the entire cohort who took the module in first semester).

The initial e-mail survey asked questions about the frequency of lecture attendance and frequency of access to the online self-study materials. The frequency of students’ online access was less evenly distributed than the frequency of attendance at lectures. Of the surveyed cohort, 29 students (96%) indicated they had accessed the online materials less than once a week, or never. In fact, 16 students (53%) did not access the online material at all.

In the e-mail survey students were also asked to rate and comment on the helpfulness for their learning of lecture attendance and the online materials. In addition to the survey asked students about the nature of feedback on their progress and their opinions regarding the best and worst aspects of the module, and they were invited to make suggestions for improving the online study components. Table 1 sets out correlational data for the scaled items in the e-mail survey.

There are several significant relationships in the table. There is a substantial and statistically significant negative correlation between frequency of attending lectures and the frequency of accessing the online materials (r = -.509, p < .01). This suggests that the more frequently a student attended the weekly lectures, the less likely they were to access the online resources and study notes. This observation is supported too by a negative correlation between the frequency of accessing the online resources and preference for mixed mode study (r = -.402, p = .028). In other words, students who attended the lectures and accessed the online material, accessed the online material less often. This also suggests a preference for the lectures over the online resources.

There are two other relevant correlations in the statistical data. There is a notable negative correlation between the frequency of attending lectures and the perception that the online resources were helpful (r = -.417, p = .02). This would indicate that the more a student attended the weekly lectures, the less helpful they perceived the online material for their learning. This finding is backed up by the highly significant positive correlation which exists in the data between the frequency of accessing online and the perception that the online resources were helpful (r = .853, p = .000). In this instance, the more the students accessed the online materials, the more they perceived them as helpful. When the usual study option (lecture attendance) is not possible, it appears that the alternative online materials are valued for learning.

In summary, there is a preference for lecture attendance. The more frequently the students attended the lectures, the less frequently the students accessed the online materials and the less helpful they perceived them to be. Those who frequently accessed the online material perceived them as helpful for their learning.

It is worthwhile noting that approximately 43% (n = 13) of the surveyed group attended weekly lectures. A further 17% (n = 5) attended lectures ‘most weeks’, and 27% (n = 8) indicated they attended ‘some weeks’. The four students who did not attend any lectures each indicated that they had a timetable clash which prevented them from attending lectures. It is evident from these figures alone that many students in this cohort chose to continue attending lectures.

This study also sought to elicit students’ reasons for these patterns of participation. Many relevant insights were recorded in the students’ open-ended responses to the e-mail survey and in the course of follow-up phone interviews with six of the survey respondents. The reasons the students gave for their patterns of attendance and participation in the Chemistry module study options are presented and discussed in the next sections of the paper.

**Attendance at Face-to-face Lectures**

Students appeared to value attending on-campus lectures with the lecturer who had designed the module in both its face-to-face and online modes. Just over half of the respondents (52%; n = 16) claimed they never accessed the online material for the Chemistry module. It appears that the face-to-face lectures and the material distributed at these lectures satisfied the learning needs of the group who did not go online.

For several students, attendance was a matter of convenience and habit:  

*I went to the lectures because I was at uni. anyway, and it saved me doing it at home; and: I’m not in the habit of skipping things; I don’t want to miss out on any important info.* The latter statement echoed a sentiment expressed by many students who felt they would miss out on something if they didn’t go to the lectures. For the interviewed students (who attended lectures) this included not missing out on the printed notes and handouts and any extra information about the assignment, as well as the lecturer's stories and anecdotes. The lecturer’s presentation style was appreciated by some of the students:  

*I think I gained some interest in some areas of discussion from the lecturer’s personal experiences and stories - remarks.* One of the interviewees commented:  

*There’s something you get from the lectures you can’t get online […] like it was more like the stories that [the lecturer] told along the way.* Some of the survey respondents wrote that they simply preferred face-to-face contact:  

*I much prefer face-to-face learning than self-instruction, and: It is always better to hear the material in person.* It was apparent from the individual interviewees comments that ‘being there motivates’ them in their study (n = 4). As two interviewees commented:  

*Yeah, if I had to do it at home, I wouldn’t do it until the week before the exam, and: If you’re doing it all online you…it requires discipline and motivation…whereas, lectures…you put it in your timetable and go every week.* Clearly some of these third year students feared their self-discipline and motivation would flag if they took up the online self-study option.
Accessing the Online Material (including lecture material)

There were four students who studied the module entirely online. Three indicated they had a timetable clash which prevented them from attending the on-campus lectures and one indicated a very heavy study/work load: "...as I already have 33 hours a week, it seemed I could skip this lecture and read the notes from the web. One student in this online-only group was also interviewed about the experience of studying the module this way. While she was satisfied that the printed lecture notes seemed pretty much the same as the online notes, her 'biggest problem' was meeting with the people in her presentation assignment group: 'If I had attended the lectures, I'd know people's faces.'

So why didn't more students, including those who attended lectures, access the online Chemistry Laboratory Practices materials? Open-ended responses to this query were notably numerous, and focussed on the resounding opinion that there was no need ('I attended the lectures so thought it was unnecessary; Didn't bother to go online, for each lecture there [are] handouts). The perceived relevance by students of the online material to the assignment is taken up in the Summary and Discussion section.

Some students in the surveyed cohort commented specifically on the challenge of computer access and the technical skill needed in order to access the online learning materials. One student claimed he/she attended face-to-face lectures because: The first time I tried the Web, I couldn't get on. Two students claimed they never remembered the material was available online, one student had initial online access problems and gave up, and another two indicated they weren’t aware that the material was online.

Combining Lecture Attendance and Access to Online Learning Material

There were ten initial survey respondents who indicated that they accessed the online notes and attended lectures. Less than half (n=14) of the survey group indicated they had accessed the material once a week or less (which may have been on one or two occasions only). A similar number agreed that the online notes helped their learning, although it is not clear if these were the same ten students. According to half (n=16) of the surveyed students, the face-to-face lectures were helpful for their learning.

The students who studied the module by combining lecture attendance and online access, held strongly to the view that they wanted to ensure they didn’t miss out on anything. As one student stated: I did both just to make sure I wasn't missing anything. Often there's additional stuff online. I went to the lectures because I was at uni. anyway, and it saved me doing it at home. Another of the interviewed students commented: I looked up a couple of online things...mainly for additional information later on for the assignment. I looked at [the lecturer’s] site for ideas. I had a gap in my timetable, so I could attend [lectures]. It is evident that for some of these third year students, lecture attendance had become a habit.

Summary and Discussion

Although all of the students in both semesters were alerted to the comprehensive online materials that were made available for self-paced study, half of the surveyed group never accessed them, preferring instead to rely on the familiar learning modes of lecture attendance, reading and analysis of handouts and readings, private study and some group work (the Semester 2 assignment). All but four respondents attended some or all of the face-to-face lectures. This preference for lectures may have been shaped by their previous years of traditional undergraduate study in what is a research-intensive university. There is some suggestion too that lecture attendance was a strategic approach in response to students’ study and personal time demands and the summative assessment focus of the module.

Attendance at on-campus lectures has become a habit for many of these third year Science students. Most of the surveyed students attended the face-to-face lectures because they were timetabled conveniently, even though an alternative study mode was provided. Students who studied only by attending the lectures, indicated that the lectures were interesting, helpful and adequate in terms of their learning in the module. The lectures also motivated many students in their study. Many of the students who both attended lectures and accessed online material were motivated by a concern not to miss anything. In the move to integrating online learning in a traditional on-campus university, student circumstances also need to be considered (eg access to computers, timetabling).

The survey and analysis of the students’ experiences of the third year chemistry module reported in this paper have also drawn attention to some particular issues in the design of flexible undergraduate science courses. The survey invited students to make suggestions for enhancing the online module, and these recommendations included the provision of:

- a ‘cyber-tutor’;
- a discussion list;
- continuous assessment (online quizzes);
- more web-based resources (databases, links).

It is noteworthy that in the case of the online-only module option, several students emphasized the need to talk to someone (face-to-face).

Flexible learning practices are being heralded as an efficient, educational ‘fix’ in a time of challenge and change in our universities (2, 3, 14, 15). In an increasingly digitized world, students are commencing university study with increasing confidence, skills and access to the Web. Yet it is evident that a sudden and unmitigated ‘move’ to web-based learning may alienate students who feel less than technically competent, and who lack access to adequate computers.
There is some evidence in chemical education research that the provision of more flexible learning opportunities encourages meaningful, independent learning (6, 7). However, students might also need some preparation for those new instructional modes and processes (16), or they may well keep relying on what they experience via traditional practices. Indeed, there is some suggestion in the present study that students’ choices had been shaped by their previous two years’ undergraduate study experiences, in that they still expected to attend lectures and have face-to-face contact with the lecturer in their third year, even when online materials for independent study were provided. To what extent do students expect face-to-face teaching and lecturing as part of their undergraduate experience? To what extent do they expect online learning experiences? Are these expectations changing as the incoming cohorts become more proficient in accessing the Web?

Knowing more about students’ responses and choices in these circumstances could assist not only with the design of individual modules and subjects, but also inform the development of three-year programs of study, for example, which would systematically integrate flexible and online learning modes and practices. In this way subject developers and course coordinators would be able to design incremental experiences of online learning environments for under-graduate students, as well as offering them a range of flexible learning options and study modes, by expanding on existing modes, practices and resources.

The combination and interpretation of quantitative and qualitative data in this small study has enabled the assessment of a particular type of web-based teaching supplement. We have drawn attention to some factors which may influence undergraduate students’ pathways and preferences in studying chemistry. The limitation of this study rests in the deliberate restriction of the methodology so as to explore a particular educational phenomenon in context. Future research should concentrate on larger cohorts, and investigate the study commitments and personal time demands which undergraduate students experience, and their strategic responses to these in terms of how they choose to structure and manage their learning when flexible options are presented to them. This recommendation is as relevant to student cohorts enrolled in other sciences and university disciplines, as it is to undergraduate chemistry students. Such a combination of quantitative and qualitative procedures will enable both the identification of relevant factors, and an extensive depiction of students’ perceptions and opinions.

The transition to more flexible teaching and learning practices in the on-campus university must not only be responsive, but also gradual. Flexible practices, such as online learning components, need to be introduced by university schools and departments from the first year as part of a staged and coordinated process. For according to some respondents in this study the best aspect of the module was the flexibility of access which it enabled. This move to increase student opportunities for learning is making small inroads into the access patterns of the undergraduate chemistry students.

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<th>Frequency of accessing online</th>
<th>Did both online and lectures</th>
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* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).
Acknowledgement
The authors are grateful to Professor Michael Prosser for his encouragement and constructive feedback on this paper.

References
6. Woodfield, B. F.; Catlin, H. R.; Waddoups, G. L.; Moore, M. S.

Appendix 1: E-mail Survey Questions
STUDENT EVALUATION SURVEY: CHEMICAL LABORATORY PRACTICES
As you know, Chemical Laboratory Practices is a compulsory module for those wishing to major in Chemistry. Currently it is available in face-to-face mode in both semesters, and the School of Chemistry is investigating the possibility of offering it as a wholly online module. This would increase the opportunity for students to study the module at more convenient times, but within the University’s semester framework.

[lecturer’s name] has offered this unit in face-to-face mode and online. We are interested in documenting your responses to these presentations so that we can inform the School of Chemistry of the “best mix” for the delivery of this module.

We are asking that you fill out the survey below. Your responses will remain anonymous and will not be identified to anyone in the School of Chemistry. The questionnaire is only being distributed now, as teaching staff have completed and submitted all the assessment for the unit.

RETURNING THE SURVEY:

When you complete this survey, please click ‘Reply’ (in your e-mail window above) and fill your responses into the ‘Reply’ version. When you click ‘Send’, it will go to Kim McShane (<k.mcshane@itl.usyd.edu.au>). Your survey information will remain confidential, and your survey will be read by the 2 researchers only. Please return this survey by [date].

Thank you.

Mary Peat Associate Dean (Teaching and Learning), Faculty of Science
Kim McShane Lecturer, Flexible & Online Learning, Institute for Teaching & Learning.

ANSWERING THE SURVEY:
Please put a cross [X] in the box which applies to you.

We would really appreciate any comments you would like to add for Questions 5 - 13.

1. Your age:
[ ] up to 21 years old
[ ] 22 years old and over
2. Your gender:
[ ] Female
[ ] Male
3. I studied Chemical Laboratory Practices in
[ ] Semester 1
[ ] Semester 2
4. Prior to studying Chemical Laboratory Practices I had accessed and used online materials and activities in other units of study.
[ ] No
[ ] Yes. Please comment on the extent to which this prepared you for studying Chemical Laboratory Practices:
5. I attended the face-to-face lectures and tutorials in Chemical Laboratory Practices
[ ] every week.
[ ] most weeks.
[ ] some weeks.
[ ] never.
Please explain your answer:
6. I accessed the online material and activities for Chemical Laboratory Practices

[ ] more than once a week.
[ ] once a week.
[ ] less than once a week.
[ ] never.

Please explain your answer:

7. I accessed the online materials and activities for Chemical Laboratory Practices AND I attended the lectures and tutorials.

[ ] No.
[ ] Yes. Please explain why you attended the face-to-face lectures:

8. The online materials and activities for Chemical Laboratory Practices helped my learning in this unit.

[ ] Strongly agree
[ ] Agree
[ ] Neither agree nor disagree
[ ] Disagree
[ ] Strongly disagree
[ ] Not applicable

Comments:

9. The face-to-face lectures in Chemical Laboratory Practices helped my learning in this unit.

[ ] Strongly agree
[ ] Agree
[ ] Neither agree nor disagree
[ ] Disagree
[ ] Strongly disagree
[ ] Not applicable

Comments:

10. I received helpful feedback on my progress from the teaching staff in the unit.

[ ] Strongly agree
[ ] Agree
[ ] Neither agree nor disagree
[ ] Disagree
[ ] Strongly disagree

Comments:

11. What is the best aspect of Chemical Laboratory Practices in your opinion?

12. What is the worst aspect of Chemical Laboratory Practices in your opinion?

13. If this unit were to be offered only online, what changes would need to be made to support the students who study it that way? (eg. increased online discussion, more continuous assessment, other suggestions?)

14. Would you be willing to discuss your experience of this unit further?

[ ] No
[ ] Yes. My contact details are:

Telephone: ____________________________
The best time to ring me is: ____________________________
E-mail: ____________________________ (optional)

Thank you for completing this survey.

Appendix 2.
FOLLOW-UP INTERVIEWS

Interview Note taking Sheet

Student No./Pseudonym: ____________________________

Date & time: ____________________________

1. Approximately how frequently did you attend the face-to-face lectures?

[ ] every week
[ ] most weeks
[ ] some weeks
[ ] never

We’d like to know a little more about your choice - of online, face-to-face or combination:
(Prompts here taken from the e-mail survey response analysis)

Online: time, flexibility, efficiency, other:
Face to face: lecturer’s presentation, notes handouts, being there motivates, lecturer’s expectations made clearer, more about the assessment, other:
Combination: convenience & flexibility (eg. missing classes), notes available for lectures, notes available before/after lectures, other:

2. Did you study this subject

[ ] face-to-face or
[ ] online
[ ] face-to-face and online in combination?

3. If combination – face-to-face and online:

3.1 Did you download and bring the online material with you to the lectures?

[ ] No
[ ] Yes ….frequency? how often?

3.2 Did you take the online materials to the live lecture?

[ ] No
[ ] Yes. If yes – how did you use the material for the lectures (before, during)?

4. If the module were offered entirely online, what would help your learning?

(i.e. What would you like to see online?)

5. Any other comments? (Thanks for helping us with this follow-up survey.)
Challenges and Rewards of Offering Peer Led Team Learning (PLTL) in A Large General Chemistry Course

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Abstract
Peer Led Team Learning is a group-based active learning strategy that complements lecture classes but poses logistical challenges for large programs like the University of Maine’s general chemistry course with 500+ students. The web-based program InterChemNet was utilized to deliver materials, facilitate administration, and evaluate the project. Data shows improved grades, retention, and student attitudes as well as benefits for the leaders.

Introduction
Peer Led Team Learning (PLTL) is an active learning strategy that is particularly well adapted to large lecture courses in that it provides an environment for structured small group work that is integrated into the curriculum but separate from the lecture period itself. The two essential but connected components of the PLTL workshop model are the format of small group, collaborative work, guided by a peer leader and the set of materials designed to be used in the workshop setting.

We introduced the method into our 500+ general chemistry course in order to see whether we could extend the benefits of a small group learning environment to students without imposing a radical change in format on what is primarily a “lecture” course. We were motivated by our success in providing an improved laboratory course to these students using InterChemNet (ICN), our locally developed web-based system for the development, delivery, and assessment of laboratory curriculum including the broad use of spectroscopic instrumentation.[1] In addition, as members of the University of Maine’s Center for Science and Mathematics Education Research, 2 we were committed both to introducing and assessing active learning strategies in our large first-year courses.

Working in cooperative small groups provides an opportunity for students to exchange ideas and challenge their own knowledge[2] and small group work has been shown to improve student academic achievement, critical thinking abilities, social skills, and self-esteem,[3] though peer assessment components are not necessarily valued by students.[4] According to Vygotsky,[5] small group work is particularly effective when instruction is offered at or slightly above a student’s own level or “zone of proximal development.” As such, undergraduate peers are particularly effective as tutors, mentors, and group leaders, and approximately 80% of all higher education institutions use some form of peer education.[6] Similarly, study groups that use peer leaders as facilitators have improved student grades and attitudes,[7] particularly with minority students.[8] One of the keys to the success of the model is the peer leader, who is an undergraduate student who has already taken and performed well in the course.[9] Peer leaders at the University of Maine are paid for their work; this is typical of many programs throughout the US. However, at some institutions, leaders receive course credit within a service-learning model.

The other essential component is the set of workshop materials which should be challenging, well integrated into the course, and, at least in part, designed for collaborative work in order to foster the social interactions that are the fabric of the PLTL model. A set of materials for general chemistry was developed by Gosser et al.[10] under NSF auspices and then published by Prentice Hall and has recently come out in a second edition.[11] These units are designed in three parts: first, a short—2 to 4 page—didactic summary of the unit being covered including some key equations; second, a self-test designed to ensure that students are minimally familiar with relevant nomenclature and basic equations to be encountered; and third, the “workshop” portion which includes conceptual questions, collaborative exercises and, eventually, some challenging problems similar to assigned homework.

We often adapted our handouts from the materials available in the literature and in some cases wrote entirely new workshops. In one example, we made a virtue of necessity when we were obliged to have several of the PLTL groups meet in the large lecture auditorium because building renovations closed off all of the smaller classrooms. In this case we developed an exercise that had students map the levels of the hydrogen atom to the steep staircases of the auditorium and then position themselves at various steps to represent an electron in a particular level; this allowed students to work in groups to make a visible analogy to the atomic system and to consider such questions as choice of zero of energy. Other exercises throughout the year included extensive use of modeling kits in a guided environment to look at molecular structure, molecular interactions, and crystal lattices.

In 1995, the U.S. National Science Foundation (NSF) sponsored the PLTL Workshop Chemistry Project to attract and retain chemistry students.[12] PLTL joined with three other projects (ChemConnections, Molecular Science, and New Traditions) in the NSF-funded Multi-initiative Dissemination (MID) project in August 2000.[13, 14] PLTL was also funded with a separate dissemination grant, the Workshop Project Associate (WPA) program, to help seed PLTL efforts at new institutions. PLTL first incorporated peer instruction and group activities into chemistry lecture courses; other disciplines such as biology, physics, and mathematics have now adopted the model as well.[15]
Over seventy-five institutions ranging from Research Universities to small community colleges have used PLTL in a variety of introductory and upper level courses, and researchers[16] have documented statistically significant improvements in student performance, attitudes, and retention rates. A variety of other chemistry programs have also presented evidence that the %ABC grades obtained by students increases upon adoption of PLTL.[17] The PLTL model has also prompted many peer leaders to consider post-graduate education and careers in teaching and science.[16, 18]

In the fall of 2000, we received a WPA grant to pilot PLTL in our general chemistry course. This allowed two of eight faculty members who regularly teach general chemistry in rotation to introduce PLTL. As we scaled-up our PLTL program we faced a number of pedagogical and logistical challenges,[19, 20] some of which we solved using the locally developed InterChemNet course management program.[1] By 2004, nearly all University of Maine chemistry faculty members who regularly teach general chemistry had used the model. This paper reviews some of the challenges to PLTL adoption and discusses how our PLTL program influenced student attitudes, affected grades and retention rates, and impacted PLTL leaders and Departmental faculty.

Challenges to PLTL Adoption
During the first four years of PLTL in Chemistry at the University of Maine, the challenge to find funds to run PLTL (chiefly for funding to pay leaders) was met with a WPA seed grant and support from the Chemistry Department, College of Liberal Arts and Sciences and the Maine Mathematics and Science Teaching Excellence Collaborative. There were three additional challenges to adopting and sustaining PLTL. The first was to integrate PLTL into the pre-existing course structure. The second was to track attendance and administer course evaluations for the 500+ PLTL students and leaders. The third challenge was to establish a training program for leaders.

Integrating PLTL into the Course.
The General Chemistry offering at the University of Maine consists of a 3 credit “lecture” course and a 1 credit “lab” (3.0 hr/wk) course. To make room for examinations outside of class time and for PLTL workshops, students also register for a 2-hour recitation. It is worth noting that PLTL has evolved from its inception as a pilot project in Fall 2000 with around 60 students and 10 leaders to full implementation after Fall 2002 with 500-600 students and 30-40 leaders (some handling more than one group). In order to connect new faculty with PLTL and to integrate PLTL into our own courses, we adapted the NSF-sponsored workshop materials to our own curriculum with faculty taking turns modifying, re-writing, and proofreading existing PLTL Workshops, as well as creating a number of new PLTL Workshops.

During typical 14-week fall semesters, PLTL groups met eight times during their scheduled recitation times, punctuated by three or four exams and various holidays and breaks. At the beginning of each semester, all PLTL instructors met to coordinate the PLTL Workshop and exam schedule as well as create a schedule for leader training and modifying existing PLTL Workshops. PLTL data from prior semesters and introductory PLTL materials are distributed at these meetings to help introduce PLTL into all lecture sections. This coordination facilitates program-wide introduction for students in lecture, leader training, project evaluation, and helps faculty new to the process to become familiar with the materials and philosophy of the University of Maine PLTL program.

Tracking Attendance and Course Evaluation.
As our PLTL program grew, tracking attendance and delivering PLTL workshop materials became a challenge. Because the challenges of managing small groups of students facilitated by multiple leaders closely resembles the problems with multiple laboratory sections taught by graduate students, we adapted our own InterChemNet laboratory management program (see http://icn2.umeche.maine.edu/) to deliver PLTL materials, to facilitate administration, and to help evaluate the project. ICN is a web-based management program developed at Maine to overcome barriers to providing an individualized, active learning environment in large laboratory programs.[1]
PLTL training programs have to be designed to ensure that they can offer a positive and consistent experience for all students in the course. The training program should correlate student attendance with final grades. Recently, we used the attendance data to evaluate the effectiveness of the program. Figure 2 shows a leader’s “instructor home page” used to record attendance, access workshops, and monitor individual student progress. The workshop schedule, and an attendance summary. The instructor can set parameters to control the timing of the availability of PLTL materials and to present students with on-line quizzes and survey questions before accessing a new workshop. Figure 2 shows a leader’s “instructor home page” used to record attendance, access workshops, and monitor individual student progress. We should note that during the transition period when PLTL was being implemented and adapted in the General Chemistry course (2000-2004), PLTL attendance was not mandatory. To encourage participation, PLTL Workshop materials were made available to every student, and were used as the bases for some exam questions. In addition, a nominal amount of (prorated) extra credit was given for PLTL attendance. Care was taken to ensure that PLTL leaders never graded student work (e.g., exams) in order to preserve their role as student advocates. All attendance and evaluation data were stored in an InterChemNet/PLTL database, accessible to course administrators. Students answered evaluation questions before and after each workshop, and course instructors could monitor anonymous student comments and responses to pinpoint areas in the curriculum needing improvement. ICN provides an online mode of communication between students and faculty and offers valuable evaluation data on student learning. We used InterChemNet to monitor student attitudes, evaluate individual workshops throughout the semester, and used the attendance data to correlate student attendance with final grades. Recently, PLTL has become fully integrated into the first semester general chemistry course, with 10% of course points assigned for preparing, attending, and participating in the Workshops.

Leader Training. PLTL training programs have to provide leadership and management skills for the leaders so that they can offer a positive and consistent experience for all students in the course.[21] The training program also needs to be sustainable from year to year as new faculty and students participate in the program. At the beginning of each fall semester, faculty members and a learning specialist meet with PLTL leaders in a 3-4 hour PLTL starter session. This session generally involves a presentation of the Workshop model, learning styles, icebreakers, the first Workshop, as well as organizational and logistical details. We found that once our PLTL training program was in place, we were able to invite returning PLTL leaders to help lead some of these activities.

During the semester, we provide each PLTL leader with the upcoming Workshop well in advance of a weekly leaders’ meeting. At the weekly meeting, faculty members and a learning specialist meet with the leaders to facilitate the leaders’ understanding of the Workshop content as well as developing leadership skills needed to run successful groups. The first order of business is to have the leaders check in. This short (10-15 min.) discussion highlights developmental issues that come up in each week of the semester (e.g., dealing with student behaviors that help or hurt the group process). Because of the size of our program, leaders were not expected to attend lectures, so lecturers would also brief leaders as to where they were in the curriculum and any potential trouble spots that might be encountered. Our experience shows that students are much more receptive to PLTL when they have had some exposure to the material in lecture before coming to Workshop. The last half hour involved the PLTL leaders breaking up into small groups (3-4) and doing portions of the Workshop as a group. In weeks preceding break weeks or exam weeks, the leader training sessions were devoted to specific topics in group dynamics or learning theory. Based on our experience with leader training, we have developed a series of flexible leader training modules and faculty guides to help new adopters of PLTL establish a training program.[19, 22]

Results.

Grade Correlation with PLTL Attendance. After the fall semester of 2002, we wanted to determine whether attending PLTL workshops improved student performance. Because attendance was encouraged but not mandatory, we were able to use the online attendance data to address this question. Overall student grades were sorted based upon the number of PLTL sessions attended as shown in Table 1. Note that any individual bonus points have been subtracted from student grades used to perform the present analysis. Though students attended an average of 5 out of 8 workshops (n=532), the average grade for students attending 0-2 sessions was 67 on a 100 point scale compared with an average grade of 78 for those students attending 7-8 sessions. This grade difference between students in the top and bottom quartiles represents a full letter grade and is statistically significant using a two-tailed t-test (p<0.001).[23] Our immediate question was, “Is a ‘good student effect’ responsible for this correlation?” In other words, was the attendance proportionally higher for students who would be expected to perform better in the class based on their previous records?

In order to explore this question, we gathered traditional indicators of student success: Scholastic Aptitude Test

(654) scores, high school rank, and prior grade point average (GPA). We performed a multivariate analysis with grade as the dependent variable against these quantities as well as the PLTL attendance. GPA, high school rank, and SAT scores account for most of the correlation between grade and PLTL attendance ($R^2=0.39$). However, PLTL attendance is also significant for some of the correlation ($R^2=0.03$).

PLTL is designed to enhance the performance of all students (it is not a remedial program). This result clearly shows a “good student effect” in which “better” students are more likely to take advantage of PLTL sessions. However all students are gaining a statistically significant benefit from PLTL. Thus, it appears that PLTL was an extremely valuable enrichment program benefiting all students, that “good” students flock to PLTL, and that PLTL attendance significantly improved grades. Another measurable effect of PLTL, that is parallel increases in %ABC grades obtained upon adoption of PLTL, is considered below.

**Success Rates.** By the end of the fall semester 2002, the lecture instructors noticed that fewer students dropped the course than in previous years. Historically, approximately 40% of our students receive a D, withdraw from, or fail the course (DWF rate ~ 40%). We thus made a longitudinal comparison of success rates (%ABC) for the Fall semester course from 1997 through 2003. This data is shown in Figure 3. Success rates for the three years prior to piloting PLTL hovered around 60%. By contrast, the success rates for the years 2001, 2002, and 2003 have averaged around 75%, an increase of about 15%. The data for 2000 and 2001 deserve special comment. The small pilot program in 2000 (n~100) resulted in a %ABC value of 62%--essentially unchanged from the pre-PLTL results. Building on the experience gained in the 2000-01 academic year, we began to scale up our PLTL effort in the Fall of 2001. Thus, in 2001, two sections (n=262) used PLTL and two sections (n=237) did not use PLTL. In that year the success rate was 78 %ABC for those using PLTL and 64% for those without, a statistically significant result (p<0.001). Such differences had not been observed between sections in previous years. We should also note that the Fall 2003 data includes 494 students in three sections of the course. Because of an unanticipated bump (25% increase) in enrollment, two extra sections were created and taught by temporary personnel. These two sections (n=192) did not formally use PLTL but some of these students attended PLTL sessions and shared PLTL material with their classmates. We decided not to try to classify these sections with regard to PLTL and do not include the %ABC for these students (77%) in Figure 3. The 15% increase in ABC rates can be understood as coming from roughly equal changes in D and F grades and in withdrawals ($\Delta D=-6\%$, $\Delta W=-4\%$, $\Delta F=-5\%$).

In conversation with PLTL groups, many students commented that PLTL helped them develop the structure and habit of studying chemistry. It is clear that these groups also provide a social network for students within the large course, and this network may be of particular value to first year students as they make the transition from high school. Increase in the %ABC rate has also been shown repeatedly in PLTL programs throughout the country;[17, 24] these results echo those for other group learning formats.

**Leader Benefits.** In addition to improving students’ grades and retention rates, PLTL provides valuable benefits for leaders. At the end of the fall semester 2002, thirty-five leaders completed a survey to reflect upon their experience. On these surveys, fourteen students commented that the experience gave them confidence and leadership skills. For example, one leader commented:

“This experience has opened my mind to facilitating more groups in the future, and perhaps one day, teaching... without this experience I don’t think I was confident in my teaching ability.”

A number of these students also suggested that the PLTL training helped them prepare for careers and interviews through leadership and team-building skills as suggested by Gosser.[12] Similarly, seven students commented that PLTL reinforced content knowledge and helped them prepare for advanced courses in chemical engineering or standardized tests such as the MCAT required for medical school. According to another leader,

“I am proud to be a PLTL leader. I regard it as an

<table>
<thead>
<tr>
<th>PLTL Sessions*</th>
<th>Average Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>67 (n=144)</td>
</tr>
<tr>
<td>3-4</td>
<td>72 (n=70)</td>
</tr>
<tr>
<td>5-6</td>
<td>75 (n=99)</td>
</tr>
<tr>
<td>7-8</td>
<td>78 (n=219)</td>
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</table>

* 0-2 sessions represents the bottom quartile

### Table 1: Overall student grades (100 point scale) vs number of PLTL sessions attended.

![Figure 3. Success rates in Fall semester General Chemistry course (%ABC). For this data, 543<n<686.](image)

### Figure 3.

Success rates in Fall semester General Chemistry course (%ABC). For this data, 543<n<686.
learning models in chemistry and recent implementations of PLTL in the Department of Physics & Astronomy and Department of Mathematics & Statistics supported by WPA grants.[25, 26] As the PLTL model has evolved, other fruitful modifications have appeared. For example, Lewis, et al.[27, 28] have reported on the use of a modified PLTL workshop structure along with guided inquiry materials developed for the Process Oriented Guided Inquiry Learning (POGIL) project[29, 30] to enhance a large general chemistry course at the University of South Florida.

Acknowledgements

We thank the 105 PLTL leaders, 2000 PLTL students, and our colleagues in the Chemistry Department, whose contributions have made PLTL not only possible but extremely rewarding. We are pleased to acknowledge support from the NSF through the WPA program and MMSTEC, an NSF Collaborative for Excellence in Teacher Preparation; the PLTL project in chemistry has also been supported by the College of Liberal Arts and Sciences and the Department of Chemistry. Support for this study was also provided by the University of Maine’s Center for Science and Mathematics Education Research (Department of Education FIE grant #R215K010106). We thank Phil Pratt of the University of Maine’s Office of Institutional Studies for his invaluable help collecting and correlating our findings with other measures of student performance.

Notes

1. A good source of information about PLTL is the web site, http://www.sci.cwru.edu/~chemwksp/index.html which also archives the electronic versions of Progressions, the Workshop Project newsletter.

2. The University of Maine’s Center for Science and Mathematics Education Research was founded in 2001 by an interdisciplinary group of science educators focused on evidence-based reform of introductory science courses, the development of discipline-appropriate pedagogies, and improved training for pre-service and in-service science teachers. More information is available at http://www.umaine.edu/center/.

3. This designation refers to The Carnegie Foundation for the Advancement of Teaching classification of institutions of higher learning (http://www.carnegiefoundation.org/). The University of Maine is classified as RU/H: Research Universities (high research activity).

4. We used %ABC as a proxy for success rate to align our results with those of other workers. Note that %ABC refers to the aggregate percentage of students earning A, B, and C grades. The traditional US scoring system based on 100 points was used: A≥90; 90>B≥80; 80>C≥70; 70>D≥60, and 60>F. Here F is a failing grade while D is marginal: an unacceptable grade for a Chemistry major, this grade is occasionally accepted by other faculties for their students who take first-year chemistry.

5. The Scholastic Aptitude Test, administered by the College Board of the Educational Testing Service (Princeton, NJ) is a standardized exam widely used by U.S. colleges and universities as one of the criteria for admission of first-year students. It is taken by students in their senior year of high school.
References


CHEMRIDDLE –
A student-friendly method of teaching and learning

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Abstract
Development of scientific attitude amongst students is one of the major objectives of science education. This article is an attempt towards that direction, where a fun and student-friendly approach to teaching and learning is presented. The characteristics of a variety of chemical compounds and processes are expressed in the form of riddles with four leading questions for each riddle. The method could be of interest to all chemical educators who are keen to find new teaching approaches. The concept of riddles could also be applied to other teaching areas at different levels.

Introduction
Teaching basic science subject like chemistry is not just a series of scientific principles and theories to be pounded into the heads of students. It requires development of concept underlying the principle of chemistry so that students can enjoy and appreciate the subject. The conventional method of teaching mostly focuses towards completion of course curriculum, and in the process students often become passive listeners. Once this stage is reached, they develop phobia and ultimately lose interest in the subject. However, if the students are made creative participants in the learning process, in such a way that each individual in the classroom has the opportunity to share his or her ideas, they feel motivated. It is this “generation of motivation” amongst the students which is the real challenge to us – the teachers. Several methods, such as group discussions, problem-solving projects, computer-assisted learning and formulations, riddles etc have been suggested in the literature based on inputs from educational researchers. Of these various suggested methods, I feel that riddles in general are intrinsically motivating and students enjoy putting their problem-solving capabilities to the task. I was wondering if riddles in chemistry can bring about the desired feedback in the form of original and independent thinking from the students. My recent experience with a large number of students is that they take the challenge in solving the riddle, enjoy the fun and satisfaction in arriving at the solution and teacher can assess their analytical ability in a better way.

In this article, a few riddles in chemistry have been presented with four leading questions for each riddle. The aim is that the students solve each of the riddle based on their understanding of the subject. Through discussion with other students and guidance from the instructor, students’ understandings and more importantly their misunderstandings should become apparent. The advantages of this active style of learning are also highlighted in a later section separately.

Riddle # 1
I look almost like benzene, but I possess one odd atom with unshared pair of electron in the ring. I cannot donate that electron pair to a proton easily. Though I have delocalized pi-electron like benzene, I undergo nucleophilic substitution easily and electrophilic substitution under drastic condition.

Questions
(a) Who am I?
(b) Why can’t I donate the electron pair of the odd atom to a proton easily?
(c) How can I attract nucleophile easily in the substitution reaction in spite of having delocalized pi-electron?
(d) Mention the name of a popular nucleophilic substitution reaction of me.

Riddle # 2
X is a class of organic compound containing same functional group at the adjacent position. It changes to other class of compound through a well-known organic rearrangement. You can prepare secondary or tertiary alcohol from the rearranged product with the help of Grignard reagent.

Questions
(a) What is the class of compound to which X belongs?
(b) Name the well-known rearrangement referred here.
(c) Mention the type of compounds formed by this rearrangement
(d) Mention the type of reaction between the rearranged product and Grignard reagent to produce secondary and tertiary alcohols.

Riddle # 3
Poor Mr. “X”! Slowly loses his strength through decomposition. He is both donor and acceptor of electrons. People use him as an antiseptic wash in surgery, in wounds, during gargle and as mouthwash. He can bleach your hair to golden-yellow color.

Questions
(a) Who is Mr. “X”?
(b) What are its decomposed products?
(c) Why can he accept as well as donate electrons?
(d) Give one example each of Mr. “X” as electron acceptor and donor.

Riddle # 4
X is a physical quantity associated with the motion of cation and anion in an electrolytic solution. This property of an ion is directly related to its velocity. The value of X
can be measured from the decrease in the concentration at anode and cathode after electrolysis. X bears an abnormal value under certain situation.

Questions
(a) Name the physical quantity.
(b) How is it related to velocity of the corresponding ion?
(c) How its value can be measured from the fall in concentration at cathode and anode?
(d) Under what situation X bears an abnormal value?

Riddle # 5
We are twin sisters, di-substituted ethylene compounds and respond to Baeyer’s test. We can produce carbon dioxide from sodium bicarbonate solution. Though both of us have two hydrogen atoms and two functional groups that are same, yet we differ in their spatial arrangement. I have higher melting point while my sister has higher boiling point. My sister can produce a derivative by intramolecular removal of water, whereas I cannot do that. All these dissimilarities are caused due to our different spatial arrangements.

Questions
(a) Identify the twin sister compounds.
(b) What are the probable functional groups present in them?
(c) Which one of them has higher melting point and which one has the higher boiling point?
(d) Name the derivative that can be formed by one of them by intramolecular removal of water.

Riddle # 6
Mrs. “X” is an anion. In presence of dilute hydrochloric acid, she starts stinking badly. Her combination with Mr. “Y” is yellow. Mrs. “X” can produce lovely violet color with sodium nitroprusside solution.

Questions
(a) Who is Mrs. “X”?
(b) Why does she start stinking in presence of dilute hydrochloric acid?
(c) What is the probable composition of the product formed due to combination of Mrs. “X” and Mr. “Y”?
(d) Write down the reaction involved in the formation of violet color.

Riddle # 7
I am a liquid compound with good smell. On treatment with water, I split into two parts. In acidic medium the rate equation of my water treatment reaction includes only me, but not water, while in the alkaline medium, alkali concentration is also included in the rate equation.

Questions
(a) Who am I?
(b) What are the two parts formed due to hydrolysis?
(c) What is the order of my hydrolysis reaction in the acid medium?
(d) What is the order of my hydrolysis reaction in the alkaline medium?

Riddle # 8
“X” and “Y” are processes related to absorption of light. While “X” is a fast process, “Y” is relatively slow as electron has to change its spin during this later process. One of them disappears immediately when the light source is cut off but the other remains for a while.

Questions
(a) Who is “X”?
(b) Who is “Y”?
(c) Among “X” and “Y” who disappears immediately when the light source is cut off?
(d) What are the transitions involved in the processes “X” and “Y”?

Riddle # 9
I am a liquid having some special property like extra stability. I am surrounded by electron cloud at top and bottom. Though I possess a group with lone pair of electron, that group can weakly attract proton. One of my reaction product is highly useful in synthetic organic chemistry. People use that product and me together to prepare red colored dye in the industry.

Questions
(a) Who am I?
(b) Why can I attract proton?
(c) What is the name of my product used in the dye preparation?
(d) What is the name of the dye?

Riddle # 10
Mr. “X” is a colorless solid compound. He is used in soap as an antiseptic. He can color the Bunsen flame to green. On heating, he produces colorless glass, which can dissolve oxides of chromium and cobalt giving deep green and deep blue colors, respectively.

Questions
(a) Who is Mr. “X”?
(b) What is the composition of colorless glass?
(c) What is the deep green compound with chromium?
(d) What is the deep blue compound with cobalt?

Discussion
The concept of the use of riddle in classroom teaching is not new. Several educational researchers have suggested that riddles are intrinsically motivating. According to Nesterenko (1994), who is an instructor of the course titled “Development of creative imagination” in the Russian city of Petrozavodsk, riddles are the best medium to assess the objects of creativity within the smallest students. According to her, many problems can be solved using riddles. They range from systematization of object’s characteristics and functions through building models to developing associative thinking. In addition, composing riddles is an art that can be measured even by smallest students.

Referring to the specific topic of our interest, namely, the chemistry riddles, Denny et al. (2000) reported a few elementary riddles that highlight some properties of elements and their compounds. According to them, the classroom teaching can be made interesting and lively by this approach. Cunningham (2005) has presented recently a few chemical riddles, each highlighting an element
Riddle # 2
(a) 1,2 glycol
(b) Pinacol-Pinacolone rearrangement
(c) Carbonyl compounds
(d) Nucleophilic addition

Riddle # 3
(a) Hydrogen peroxide
(b) Hydrogen peroxide is decomposed to water and oxygen
(c) Since it contains oxygen in the intermediate oxidation state of –1, it is oxidized to superoxide and is reduced to oxide.
(d) It oxidizes iodide (I-) to iodine (I₂) and can reduce potassium permanganate (KMnO₄) to Mn²⁺-salt.

Riddle # 4
(a) Transport number
(b) T+ = Transport number of cation = U+(U+ + U-), where U+ = velocity of cation and U- = velocity of anion T- = Transport number of anion = U-/U+ + U-
(c) T+ = Fall in concentration at anode/ Fall in concentration at anode and cathode
(d) In the concentrated solution of some partially dissociated electrolyte, cation possesses abnormal value of transport number.

Riddle # 5
(a) Maleic acid and Fumaric acid
(b) Double bond and carboxylic acid group
(c) Fumaric acid has higher melting point whereas Maleic acid has higher boiling point
(d) Maleic anhydride

Riddle # 6
(a) Sulfide anion
(b) Due to formation of hydrogen sulfide (H₂S) gas having smell of rotten egg
(c) Cadmium sulfide (CdS)
(d) S²⁻ + [Fe(CN)₆]₃⁻ → [Fe(CN)₆]S⁺

Riddle # 7
(a) Ester (e.g. CH₃COOCH₂)
(b) CH₂COOCH₂ + H₂O = CH₃COOH + CH₃OH
(c) Pseudo first order
(d) Second order

Riddle # 8
(a) Fluorescence
(b) Phosphorescence
(c) Process “X” (fluorescence)
(d) Transition for “X”: S₁ to S₀

Riddle # 9
(a) Aniline
(b) Because of the presence of lone pair of electron on nitrogen atoms
(c) Benzene diazonium salt
(d) Azo dye

Riddle # 10
(a) Borax (Na₂B₄O₇·10H₂O)
(b) The colorless glass like bead is a mixture of sodium metaborate and boric anhydride
(c) Chromium metaborate (Cr(BO₂)₃) which is deep green
(d) Cobalt metaborate (Co(BO₂)₂) which is deep blue
Contents

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Letter to the Editor</td>
<td>Kieran F. Lim (林 百 君)</td>
<td>5</td>
</tr>
<tr>
<td>Author response</td>
<td>Vladimir M. Petruševski and Marina Monković</td>
<td></td>
</tr>
<tr>
<td>* From APCELL to ACELL and beyond – Expanding a multi-institution project for laboratory-based teaching and learning</td>
<td>Ian M. Jamie, Justin R. Read, Simon C. Barrie, Robert B. Bucat, Mark A. Buntine, Geoffrey T. Crisp, Adrian V. George, and Scott H. Kable</td>
<td>7</td>
</tr>
<tr>
<td>* Thermodynamics of the NO₂ - N₂O₄ equilibrium by FTIR: An APCELL experiment</td>
<td>William E. Price, David W.T. Griffith and Stephen R. Wilson</td>
<td>14</td>
</tr>
<tr>
<td>* Evaluation of the application of a flexible delivery approach to first year chemistry students</td>
<td>Marylou Molphy</td>
<td>18</td>
</tr>
<tr>
<td>* Playing it safe? Students’ study preferences in a flexible chemistry module</td>
<td>Kim McShane, Mary Peat and Anthony F. Masters</td>
<td>24</td>
</tr>
<tr>
<td>* Challenges and rewards of offering peer led team learning (PLTL) in a large general chemistry course</td>
<td>Barbara N. Stewart, François G. Amar and Mitchell R. M. Bruce</td>
<td>31</td>
</tr>
<tr>
<td>* CHEMRIDDLE – A student-friendly method of teaching and learning</td>
<td>Mala Das Sharma</td>
<td>36</td>
</tr>
</tbody>
</table>

* Refereed papers

Cover photographs: Courtesy of Dr Ian Jamie and Mr Justin Read - Participants in the February 2006 ACELL workshop.