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.

Articles

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.

1. We prefer to handle all submissions electronically. Our preference is for Microsoft Word files in Mac format. However, you can send files from any common Windows, DOS or Macintosh word processor.
2. On another separate page provide an abstract of 50 to 100 words;
3. All photographs should be scanned and saved in JPEG format.
4. All chemistry structures, and schemes should follow the guidelines set for ACS publications. It is preferred that Schemes, Tables etc be arranged to fit in a column 7 cm wide, although full page width will be accepted.

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 this addition to the APCELL series of experiments, **McNaughton** describes an experiment for identification of pharmaceutical drugs such as aspirin, salicylic acid and paracetamol by IR and Raman spectroscopy in conjunction with a searchable database. In order to improve the students' theoretical understanding of these techniques, the measurements are preceded by use of computer simulation software that animates molecular vibrations for a range of small molecules. Students learn to visualise the molecular vibrational motions, and relate these to the spectra observed. As usual, the description is accompanied by an educational analysis that addresses the questions '*What will students learn*?', '*How will students learn it*?', and '*How will both staff and students know that the students have achieved the intended learning*?'.

It is increasingly common for tertiary chemistry departments to offer some form of 'outreach' programme to give secondary students a taste of what chemistry is all about. Massey University in New Zealand has developed what might be called an 'inreach' programme by inviting students in their penultimate school year into the university for a laboratory-workshop session. **Wright and Jull** describe the objectives, the details, and the rationale behind this surprisingly inexpensive way of giving students and their teachers a rewarding learning experience in chemistry.

In a research study with 15 to 17 year-old students in Singapore, **Tan and Treagust** used two-tier multiple-choice diagnostic tests to probe students' explanations for simple 'inorganic' reactions involving precipitation in aqueous solution. Students had difficulties in understanding the reactions involved in the testing for cations and the authors found strong evidence for visualisation of processes that is not consistent with that of the chemistry community. Speculation about the reasons for the conceptions identified included conceptual interference and perceptually dominated thinking.

Continuing the international contributions to *this Journal*, **Dhinsda** in Brunei reports on a research study into the understandings of pre-service science teachers' conceptions of the acid-base-related concepts *pH*, *acid*, *base* and *neutral*. Very limited, narrow and 'textbooky' understandings were found to be common. There are enough research studies on understandings of these concepts by students in a range of levels in other parts of the world to suggest that these findings cannot be dismissed as peculiar to Brunei, or to the competence of its teachers - any more than in other countries.

These days there is considerable focus on learning generic, transferable skills within the context of courses in science. At Curtin University of Technology, the Science and Mathematics Education Centre (SMEC) offers a postgraduate unit in which students write critical reviews of science-related books. Published here are reviews by science teachers **Clark** (*Chemistry in the Marketplace*, Selinger) and **Brown** (*The Periodic Kingdom*, Atkins). These reviews serve the double purpose of demonstrating the nature of this exercise, as well as informing others about these publications.

Finally, **Harlen** describes a simple apparatus to demonstrate the reduction of metal oxides using bench gas.

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Editorial

LEAPing into Chemistry

We describe here what we believe was a very successful teaching and learning project from the Division of Engineering and Science at Curtin University of Technology. The real success of the project was not simply the successfully completed projects, but rather its impact on the teaching and learning ethos within the Division. The project, entitled *Developing Flexible Learning Environments* was funded for a total of three years as one of Curtin's 13 Learning Effectiveness Alliance Program (LEAP) projects. This project identified two principal areas to target, (i) the development of more flexible assessment and feedback procedures and (ii) increasing the flexibility of laboratory activities. Staff within the Division were invited to submit an "expression of interest" to carry out small projects that addressed either of these areas. These mini-projects, lasting one year, received a maximum of $8,400 funding from LEAP for teaching buyout and were selected through a peer review process according to the following criteria:

- alignment with the project objectives and the Division's Teaching and Learning plan,
- strategic importance of the initiative,
- viability of the proposal, with respect to time requested,
- clear identification of expected outcomes,
- appropriateness of evaluation strategies,
- timeline for development phase,
- teams consisted of at least two staff members,
- departmental support of at least two hours time release per week for the project (LEAP will then fund up to four hours per week).

Over the past three years seventeen teams involving thirty staff from ten departments have participated in this LEAP project. Most of the staff involved in this project had no prior experience in the development of educational projects and in our opinion the LEAP support structure was a critical factor in their successful participation. This support was not just financial, but included some professional development in education for academic scientists and engineers. Probably the most important support was the fortnightly meetings, lasting approximately 90 minutes. These usually involved a pizza lunch during which networking took place, an issues/news segment, a major report from one of the teams (30 minutes) and then a quick progress report from the other teams. Members of previous years' teams were asked to become "Peer Mentors" for the new teams and usually attended these meetings in this capacity. These meeting also provided a forum for the sharing of technical know-how and an opportunity to discuss the pros and cons of aspects of each of the mini-projects. For example the issue of assessment of on-line activities was debated at length and the overall result was a community of better informed educators.

Of the seventeen mini-projects approximately half focused on flexible laboratory activities. Five mini-projects involved the staff of the Department of Applied Chemistry and we will briefly describe these as an example of scope of the projects within this LEAP project. Two projects involved the development of virtual experiments on the web, two in developing pre-laboratory activities (one web based) and one in developing on-line tutorials/quizzes. Abstracts of all 17 projects can be found at: http://www.cage.curtin.edu.au/gis/leap/overview.html.

The virtual laboratory experiments were chosen to complement the existing laboratory program and involved simulations and associated quizzes. They provided students with enhanced opportunities for experimental design, an opportunity to study experiments/phenomena not readily available in laboratory classes, gave them increased data analysis training (as less time was taken up with data collection) and were used to reinforce theoretical phenomena with simulations. Four virtual labs, "Titration Curves and Buffers", "Chemical Equilibrium", "Initial Rates" and "Integrated Rate Laws" have been developed.

Students who adequately prepare for a laboratory class are expected to be more successful in attaining the objectives of the class, and it was this premise that inspired the two projects associated with prelabs. One project targeted students who had not previously studied chemistry and had little or no experience with laboratory work, the other focused on the second year physical chemistry laboratory course. The former project, in collaboration with staff from Curtin's Science and Mathematics Education Centre, aimed at reducing student anxiety and increasing their preparation by providing short prelab quizzes on-line. These quizzes generally took students about 10-15 minutes to complete and included questions involving identifying apparatus and doing sample calculations, while providing immediate feedback. The second prelab project involved redesigning the laboratory program such that the prelab became a significant component of the experiments. Students were now required to do a significant proportion of the work associated with the laboratory experiment prior to entering the lab. This included writing the introduction, carrying out sample calculations to determine expected results and in some cases plotting the expected graphs.

The final project from Chemistry involved developing a series of on-line quizzes for the major first year chemistry units. Although these quizzes contributed towards the students' assessment the principal aim was to provide students with a resource for practice and skills development. Textbook publisher supplied questions were used to build these quizzes and feedback was then incorporated into the answers. The questions in the quizzes were randomised and students were allowed three attempts, with the best result being used for assessment.

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The identification of drugs by infrared and Raman spectroscopy: An APCELL experiment.*

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Modern vibrational molecular spectroscopy is a powerful analytical technique that is taught in all chemistry courses and is widely used in all branches of chemistry, materials science and increasingly in the biosciences. In modern instruments the necessary computer interface provides a facility that greatly enhances the power and range of applications but is often thought of by students as a “black box”. In addition to learning the basic vibrational theory and instrumentation it is necessary for students to also learn how to best use the computing power that accompanies these spectroscopic techniques.

This experiment was designed to support the basic theory of vibrational spectroscopy, spectroscopic instrumentation and the application of vibrational spectroscopy to chemical and forensic analysis. The first part of the exercise involves using computer simulation software to animate molecular vibrations and providing a medium that engages most students and encourages active learning. After an hour of exploring molecules ranging from diatomics to small drugs, students are capable of visualizing the molecular vibrational motions and relating these motions to predicted IR and Raman spectra. This process also leads to a better understanding of the basic concepts.

The experimental work is quite simple but, providing the automated instrumental functions are turned off and the students are required to step their way through the collection of spectra, it provides an excellent support for the instrumental background covered through lectures. The computer manipulation is quite straightforward for the computer literate student, but challenging for those that lack confidence in using modern software. The process of transferring data, manipulating baselines and carrying out a database search provides a further opportunity for students to gain confidence in using computer interfaces and accessing databases. The outcomes of the database searching lead students to critically access their experimental spectra because the database search fails if the spectra have not been recorded optimally. At the end of the practical exercise students will also realize that without a good knowledge of the fundamentals and the instrumental methods and good experimental technique database searching is of no use.

The exercise was developed for a 2nd year unit in Instrumental and Forensic Chemistry with the original idea of identifying micro-fibres and paint chips. The drug identification was eventually chosen simply because it requires no special accessories for the infrared. A laboratory equipped with diamond anvil cells or single bounce pressure ATR systems would provide an opportunity to base the exercise around a more appropriate forensic topic and expose students to modern IR methodology.

Educational Template

Section 1 - Summary of the Experiment

1.1 Experiment Title

Infrared and Raman Spectroscopy for the identification of drugs

1.2 Description of the Experiment

Students carry out the exercise at Monash as part of a level 2 subject “Instrumental and Forensic Chemistry” although it is appropriate for any subject that covers the theory and practical use of infrared and Raman spectroscopy. The notes are written in the context of forensic science and this context appeals to most students. In this exercise students firstly reinforce their knowledge of vibrational spectroscopy theory using a computer program, record IR and Raman spectra of a common pharmaceutical drug and then identify the drug using a searchable database.

The aims of the practical are as follows:

Using a computer simulation program **Animol**

i. Investigate the spectra of small molecules and correlate the bands with vibrational modes.

ii. Obtain a prediction of vibrational spectra of aspirin (acetyl salicylate), salicylic acid and paracetamol (4-hydroxyacetanilide) and compare the spectra. *Note. These could be any useful molecules you wish to enter into the Animol program.*

Record the infrared spectrum of a common pharmaceutical drug using a KBr matrix technique.

Search an infrared spectral database to identify the drug.
Record or obtain the Raman spectrum of a common pharmaceutical drug.

Search a Raman database to identify the drug.
Gain experience in data transfer and spectral manipulation.

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[*] The complete documentation for this experiment is freely available on the APCELL web site [www.apcell.org]. It includes the educational template, a set of student notes, demonstrator notes and technical notes to allow ready implementation into a new laboratory.

The use of the computer simulation program allows the students to reinforce their theoretical knowledge whilst visualizing vibrational modes and relating these modes directly to predicted spectra. Students then have control over their rate of learning and depth of learning. The experimental part is straightforward and kept simple because it is often the first time students have used IR and Raman spectroscopy. The nature of the experiment can allow them to learn about the instrumentation, although this can be de-emphasized for students not involved in instrumentation. Although students should satisfactorily identify the drug in question through database searching they will realise through the practical that a depth of knowledge is required to search the database and achieve the correct result.

1.3 Course Context and Students' Required Knowledge and Skills

The experiment is closely linked to the "Instrumental and Forensic Chemistry" subject at Monash although it would be equally at home in any analytical spectroscopy, physical chemistry or analysis course. Even students doing courses in synthetic chemistry would find this a useful exercise.

Students require knowledge of the theory and instrumentation of IR and Raman spectroscopy and the ability to quickly come to terms with an interactive computer program. The sample preparation for the infrared requires a little skill that is picked up by most students quickly. They also require a familiarity with, or a desire to learn how to transfer data between computers and how to find their way around new computer packages.

1.4 Time Required to Complete

Prior to Lab	30 min
In Laboratory	5 hours
After Laboratory	1 hour

1.5 Other Comments

The exercise consists of the 3 components of spectral measurement, computer visualization and database searching. For shorter prac periods the exercise can be reduced by the removal of one of these components. Similarly if a Raman instrument is not available then the Raman experimental part can be omitted.

The major criticism in the workshop was the length of the prac and the wide variety of tasks expected so I should come clean on how we run this now at Monash. It is split into 2x4 hour pracs.

1. Consists of the Animol exercise together with obtaining IR (nujol mull) and Raman spectra of the analgesics used in the Animol exercise. Students then simply identify the analgesics from the spectra and note the spectral differences. (This is used in 2 2nd year subjects (Chemistry of Life and The Instrumental and Forensic Chemistry)
2. Consists of the Practical part and database searching part only and is used in Instrumental and Forensic Chemistry only.

Both of these pracs are completed by the students in <4hours.

Section 2 – Educational Analysis

Learning Outcomes *What will students learn?*	**Process** *How will students learn it?*	**Assessment** *How will staff know students have learnt it?* *How will students know they have learnt it?*

Theoretical and Conceptual Knowledge

Clarification of the concept of normal modes of vibration.	By observing in 3D the normal vibrational modes of small molecules. By comparing the vibrational modes of a number of small molecules	The students will answer questions that require this knowledge on a proforma sheet. Demonstrators will observe the progress of students through the interactive program and mark the proformas.
Clarification of the nature of functional group vibrations in larger molecules	By observing in 3D the vibrational modes of larger molecules and how they vary. By correlating the wavenumber positions of predicted and measured vibrational modes with tables.	The students will answer questions that use this knowledge on a proforma sheet.

Insight into the selection rules of vibrational spectroscopy and complementary nature of IR and Raman.	By comparing IR and Raman spectra both predicted and measured	The students will answer questions that require this knowledge on a proforma sheet.
A knowledge of the theory of IR and Raman instrumentation.	By recording spectra themselves and making decisions on how to best record spectra. By manipulation of the various components of the instrumentation	The students will successfully record high quality spectra which will be assessed by the demonstrator. The demonstrator should also question them about how the instrumentation works during the operation of the instruments

Scientific and Practical Skills

How to effectively record IR and Raman spectra.	By recording spectra themselves and making decisions on how to best record spectra. By manipulation of the various components of the instrumentation.	The students will successfully record high quality spectra which will be assessed by the demonstrator. Demonstrators will assess the success or otherwise of the database search.
Learn some techniques of sample preparation for IR and Raman.	By preparing KBr discs via a pellet press and by using a microscope attached to the Raman instrument.	By observing the appearance of the KBr disc and the quality of the spectra recorded.
How to manipulate and pre-process spectral data prior to database searching.	Direct application of baseline removal routine and removal of cosmic ray spikes prior to database searching.	By successful removal of the features and successful search of the database. Demonstrators will observe the procedures undertaken.
An awareness of the limitations of database searching and how a knowledge of instrumentation and fundamental spectroscopy is still an essential component for an analytical scientist.	By observing the failure of database searching with inappropriate spectra and then its success when the spectra have been manipulated or corrected. Success will only be achieved when their knowledge is used.	By successful use of the database searching and the correct conclusions from the experiment. As written in the practical report.

Generic Skills

Students will become familiar with the use of computers in science and gain skills in their use.	By digital data collection, digital manipulation of the data, by using an interactive modelling and simulation program and by manipulating and searching databases.	By observing the students successfully using the technology and completing the exercise.

Students will become more aware that despite the wide use of computers it is still essential to have the correct science background to solve an analytical problem.	Through the practical they will recognize that decisions can only be made with sufficient background theory in spectroscopy and instrumentation and that a final answer to problem is only possible with that background knowledge.	By the correct decision paths being made through the exercise.
They will learn how to progress through an analytical problem using critical judgement and identify a chemical compound using spectroscopy.	They will only get the same result using IR and Raman spectroscopy if the correct decisions are made through the exercise.	By assessing the final outcome
How to communicate results in a written report.	By writing a report to explain how they arrived at their conclusion.	By assessment of the final report.

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?

Yes, The simulation program was especially useful in achieving this.

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

It is a good example of a modern way of introducing and using a spectroscopic technique.

3.3 Did you find this experiment interesting? If so, what aspects of this experiment did you find interesting? If not, why not?

Yes, The forensic angle was interesting and we got to use a range of instruments and computer software.

3.4 Can the experiment be completed comfortably in the allocated time? Is there time to reflect on the tasks while performing them?

Generally more time is required to carry through the range of experiments. It may be better to concentrate on just some parts of the experiment in the available time.

NB. This experiment was carried out in 3 hours for the student analysis but without the IR part

3.5 Does this experiment require teamwork and if so, in what way? Was this aspect of the experiment beneficial?

Working through the Animol program and the database searching as a pair was a good way to learn.

3.6 Did you have the opportunity to take responsibility for your own learning, and to be active as learners?

We did although more time was needed to do this properly.

3.7 Does this experiment provide for the possibility of a range of student abilities and interests? If so, how?

It is quite challenging for most students, although aspects of it can be carried out successfully without a good background.

3.8 Did the laboratory notes, demonstrators' guidance and any other resources help you in learning from this experiment? If so, how?

It was a good learning experience all round.

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

It was a lot to ask in the time available.

3.10 What improvements could be made to this experiment?

There is too much for a single lab session and it could usefully be made into 2 or more sessions.. More instructions on the software would be useful.

3.11 Other Comments

[no responses]

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Inviting students into chemistry: A chemistry "field trip"

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Abstract

A project aimed at enhancing the high school – university relationship has been implemented in 2002 at Massey University. The project brings classes of high school chemistry students into the university for a laboratory-workshop session in the students' penultimate year of schooling. The aim is to help students learn a significant piece of their curriculum and at the same time give them an experience of working in the tertiary environment and a glimpse of the connections between what they are learning and chemical research. Large scale uptake of the project by teachers together with an evaluative survey indicate that the project is achieving each of the aims and provide pointers for further development.

Introduction

Initiatives that engender student interest in continuing to study chemistry are continually required because of competing demand on students. This paper describes a new programme targeting student retention in chemistry across the secondary- tertiary transition.

In the modern high school, chemistry is often seen as one of the traditional subjects that is hard, abstract, removed from everyday relevance and with career options that are far from obvious. A range of initiatives has been described to support chemistry teachers in their efforts to combat this view including outreach programmes (Waldman 1996) and teacher workshops (Venugopalan, 1990).

In this case a decision was made to bring students to the university rather than take chemistry into the high school classroom. It was felt that there were significant advantages in terms of chemical learning outcomes as well as affective outcomes and these combined with pragmatic issues of cost and time.

The following description of the initiative demonstrates how such a project can be established and evaluated.

Objectives

- To give students the opportunity to learn a part of their high school curriculum.
- To give students a chance to learning chemistry in the university setting.
- To show students how the chemistry they are learning relates to active research fields.
- To build the relationship between the university and teachers involved in the visits.

The Initiative

The initiative involves inviting chemistry teachers to bring their classes to the university to carry out a two-hour laboratory workshop. The on-campus event is backed up with pre- and post-event in-school sessions delivered online. The aim is to give the students an experience of the university while delivering a serious component of the high school chemistry curriculum that is difficult for teachers to deliver in the school setting.

The initiative started in 2002 and has attracted about half of the year 12 high school chemistry students in the catchment area of Massey University's Palmerston North Campus. This has amounted to more than 800 students participating in the event.

Figure 1. Students preparing polypyrrole

Target Group

It was decided to focus the initiative on Year 12 students who, in New Zealand, are completing their penultimate year at school. The event is offered in the second half of the academic year because:

Most students in Year 12 study chemistry as a single subject for the first time and have covered sufficient material in the first half of the year to make a laboratory experiment that integrates a number of areas useful.

At the same time many of the students are starting to consider their futures beyond high school and therefore will benefit from the University experience.

Year 12 is a better time for the experience than Year 13 because the time pressure on teachers and students is high in Year 13 due to external examinations. Further, Year 13 student are often well down the track of deciding what to do next and where to go.

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The Experiments

The topics to be covered in the laboratory workshops were chosen based on the Year 12 curriculum. At this stage, teachers are completing an introduction to organic chemistry and may have completed a unit on redox chemistry and possibly introduced their students to polymers. Earlier in the year, students are likely to have covered the mole concept and so an element of quantitative chemistry was also considered important.

Two experiments were chosen so that teachers could be offered a choice and thereby make a match with their teaching more likely.

Limonene isolation and reactions: This experiment involves a crude distillation of the essential oil from orange peel (Marmor, 1981). The experiment was developed to give a reasonably reliable 250-400 mg yield of oil that could be isolated by pipette straight from the aqueous distillate. Tests then illustrate the reactivity of the double bonds in the compound. The reaction with bromine is carried out quantitatively so that the students detect the presence of the two double bonds in the molecule.

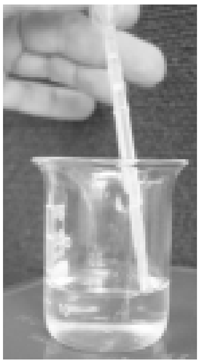

***Figure 2** Limonene is isolated by pipetting the oil off the distillate.*

The experiment is accompanied by a molecular modelling exercise in the Chemistry Computing Laboratory in which students explore the molecular structure of the compound and some elementary ideas of stereochemistry.

The chemistry being carried out in the lab is linked to the Department's research strength in natural products and biological chemistry during a 10-minute visit to an appropriate research laboratory.

Conducting polymers: Students synthesise a polypyrrole film (Sadik, 1999) and carry out a series of tests on the polymer in this experiment. Very simple equipment was developed that is both cheap and reliable and does not confuse the underlying chemistry. Once isolated, the conductivity and a series of other physical and chemical tests are carried out on the piece of polypyrrole and the results compared with those from an equivalent piece of black PVC. A quantitative element is added to the experiment in the determination of the yield of polymer. As with the limonene, the experiment is accompanied by a molecular modelling exercise and a visit to the Department's Nanomaterials Research Centre.

Pre and Post-Event Tutorials

Students are invited into the online pre-laboratory tutorial with a drag-and-drop exercise to familiarise them with the equipment they will use. They also complete a short tutorial that covers the types of reactions they will carry out (but not the specific reaction). Safety issues are raised in an exercise that gets students to locate safety features on a floor plan of the laboratory they will use.

The post-laboratory exercise covers the completion of the quantative side of the experiment and checks that the students have understood the major conclusions from the experiment.

Running the Laboratory-Workshop

The events were designed as co-operative learning exercises in which the students work in groups of two or three. This design is intended to minimise the hurdle for students working in a foreign environment and also to make the execution of the experiment as efficient as possible.

The laboratory sessions are broken into several parts allowing practical detail to be explained in easy steps and students are encouraged to think about the chemistry being carried out as they progressed through each stage.

Using the two-hour time frame for the laboratory session allows for completion of the practical, a situation that is often difficult to achieve in school timetables. In both experiments there is a take-home component to encourage the idea that the chemistry activity has been successfully completed.

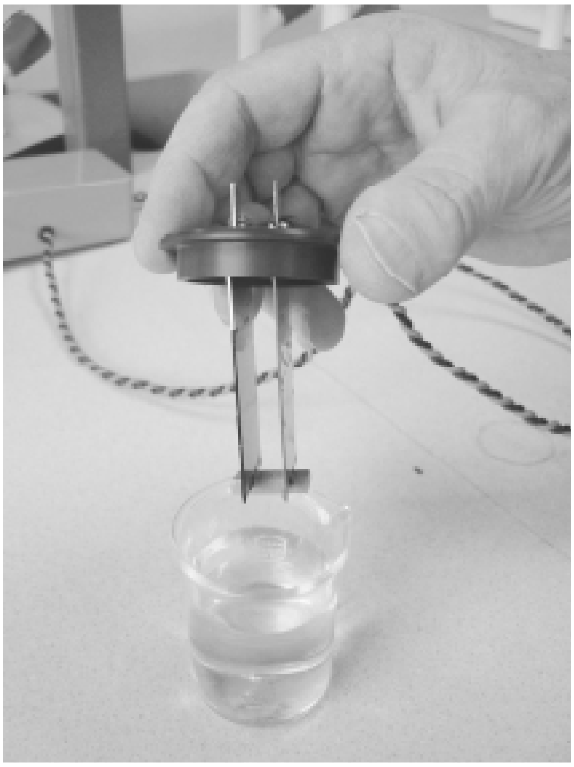

Figure 3. Putting together the electrochemical cell.

Promotion of the study of chemistry at tertiary level is primarily achieved by direct dialogue with students on an individual or small group basis. Inclusion of academic staff in the operation of the laboratory provides an opportunity for staff interaction with students and teachers. Some of the students' conceptions of university study and staff were challenged by this interaction.

Professional development

At the same time the teachers who accompany the class have an opportunity to talk to academic staff and see the laboratories. This provides an opportunity for some professional development as well as opening up valuable school/university communication channels for teachers. Teachers are an integral part of the program, assisting in the running of the practical and ensuring that health and safety issues are met. They readily relate to the laboratory environment and are perceived by the students to be skilled in the area.

A number of the teachers who brought their class to the event described being isolated in their school as the sole chemistry specialist. Furthering of links between the university and the high school teachers is a way to give support to these teachers.

Cost

The two important components involved in running the events are the real cost and the time cost for staff involved. The cost of materials for the year of operation have been modest because most of the equipment was already available in the laboratory and very modest amounts of consumable chemicals have been used. Current estimates put the cost at less than $NZ1000.

The construction of the electrochemical cells and power supplies has contributed a one-off cost of a few hundred dollars.

The low cost of the event for the Department has meant that the project is to be run again without charge to students. Schools still have to arrange transport which is a significant cost for out-of-town schools.

In terms of time commitments, one member of staff has run all the sessions and is supported by a roster of other staff who come in to help once or twice during the semester. The bookings for the laboratory are made in slots where the lab is otherwise empty and the equipment is stored in plastic trays to minimise setup time for the laboratory technicians.

Evaluation

A major indicator of the success of the event lies in the uptake by teachers. More than 800 students experienced the event from 34 schools in 40 individual laboratory sessions.

Approximately 70% of the classes opted for the limonene experiment, probably indicating that the timing of the event matched the introduction of students to organic chemistry. An evaluation form was given to teachers and has been used to gauge the feelings of teachers after the event. The evaluation form contains a series of Likert scale responses followed by a request for general comments.

For the Likert scale responses teachers were asked to indicate the usefulness of different aspects of the event on a 1 to 5 scale set with 5 representing very useful.

The results show that the major objectives of the initiative have been achieved. The rating for the laboratory session was very high, and the event is achieving the affective outcomes in terms of students gaining a feeling for the tertiary environment and promoting continued study of chemistry.

Question (1 to 5 Likert scale)	**Average response**
The experiment as experienced	4.8
The computer modelling session	3.5
The pre-lab tutorial	3.6
The visit to the university as a tertiary facility	4.6
The value of the event in terms of promoting chemistry as a subject choice.	4.2

The evaluation also gave an indication where further development could be useful in terms of the outside the lab exercises.

One of the major initial concerns was whether or not the challenge of the experiments had been set appropriately. A separate item in the evaluation showed two thirds of teachers thought the level of difficulty was just right and the other third thought the level of difficulty slightly too high. This is probably a reasonable level of challenge given that students need to be left with an impression that university is a place where they will be intellectually challenged.

Other insights have come from the anecdotal comments on the evaluation forms:

> *"The workshop helped to demystify the subject."*
>
> *"They really enjoyed producing something that was useful rather than just observing and explaining changes."*
>
> *"An evaluation of the students showed that 15 out of 17 thought 'it was well worth doing'"*
>
> *"The students enjoyed working in a well equipped lab, with so much space. For both teachers and students it was an enjoyable experience."*

Conclusions

The initiative appears to have achieved its major objectives and is having a positive impact on teachers and academic staff as well as students.

A significant proportion of the chemistry students in the region are being given an experience of doing chemistry in a university setting at a time when they are starting to consider their career after high school.

The fact that students are being given a learning experience that relates directly to the curriculum is undoubtedly one of the contributing factors to the uptake of the events by teachers.

The overwhelmingly positive response by teachers means that they are also benefiting from the experience. This provides an excellent opportunity for informal professional development for teachers. It is intended to develop this aspect of the event in future years.

Thirdly, the event means that academic staff have contact with almost all the teachers in the region while at the same time contributing to the learning experience of the students. There is an obvious gain for staff in the sense that they are more likely to be able to relate to students when they teach in the first year programme at university.

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In summary, this LEAP project brought together a large number of staff from the Division of Engineering and Science and had a significant influence in lifting the profile of teaching and learning within the Division. The resulting network of academic scientists and engineers from across the Division would not have been possible without the LEAP support and consequently, the current networking and sharing of ideas and skills would not have occurred. Staff involved in the mini-projects generally spent more time than the funding provided, but thought the process very worthwhile and appreciated the support to implement their initiatives. The outcomes of these mini-projects were presented at annual LEAP Expos and have been presented at 15 conferences.

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It’s a displacement reaction because sodium ions are more reactive than zinc ions

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Abstract

Grade 10 (15 to 17 years old) students have difficulties in understanding ion-exchange reactions and complex salt formation involved in the tests for cations in basic inorganic chemistry qualitative analysis. Many students believed that when an insoluble hydroxide was produced from the reaction between an unknown cation and a hydroxide ion, a more reactive ion displaced a less reactive ion to form the precipitate. Students also explained that the reaction between several hydroxides and excess alkali as the precipitate dissolved when excess alkali was added because more solvent was added or that no new reagent was added and no further reaction was seen. Possible reasons proposed for such student conceptions included conceptual interference and perceptually-dominated thinking.

Introduction

Grade 10 students (15 to 17 years old) in Singapore sit for a national examination, the General Certificate of Education Ordinary Level (O-level) examinations, at the end of their school year. Students taking chemistry as a subject need to take one practical and two written papers. There is usually one question in the practical paper on basic inorganic chemistry qualitative analysis which requires students to carry out a series of procedures, observe and record what happens, and make inferences based on their observations.

Teachers in Singapore usually begin teaching qualitative analysis by reviewing the reactions involved and demonstrating some procedures that the students need to carry out. Using commercially available workbooks or teacher-prepared worksheets, students then do a series of tests for various cations, anions, gases, oxidising and reducing agents. After this initial stage, students will start on past years’ examination questions to prepare for the practical paper. In the one-off practical examinations, students are assessed solely on their practical reports, and in qualitative analysis, this translates to the students’ written observations of the reactions which occur when they execute a series of procedures, and to a lesser extent, the inferences they make based on their observations.

The content framework for qualitative analysis is given in Tan (2002). To understand the reactions in qualitative analysis, students mainly need to apply the knowledge they learned in the topic, ‘Acids, Bases and Salts’. However, several studies (e.g. Carr, 1984; Hand & Treagust, 1988; Nakhleh & Krajcik, 1994; Schmidt, 1991, 1997) have found students have difficulties understanding the concepts and reactions of acids, bases and salts. For example, in qualitative analysis, many anions and cations are identified using ion-exchange reactions resulting in the formation of precipitates – Butts and Smith (1987) found that students could not relate the formation of a precipitate in an ion-exchange reaction to the low solubility of the salt, while Boo (1998), and Boo and Watson (2001) found that students believed the driving force for an ion-exchange reaction was the difference in reactivity between the metallic elements present in compounds involved.

Purpose of the study

The purpose of the study is to determine Grade 10 students’ understanding of the ion-exchange reactions and complex salt formation involved in the tests for cations in basic inorganic qualitative analysis.

Method and procedure

In this study, interviews, a free response test in which students have to justify their answers, and a two-tier multiple choice diagnostic instrument (Treagust, 1995) were used to determine students’ understanding of the procedures and reactions involved in qualitative analysis. Items in a two-tier multiple choice diagnostic instruments are specifically designed to identify alternative conceptions and misunderstandings in a limited and clearly defined content area. The first part of each item consists of a multiple choice content question having usually two or three choices. The second part of each item contains a set of four or five possible reasons for the answer to the first part. Incorrect reasons are derived from actual student alternative conceptions gathered from the literature, interviews and written tests. The Qualitative Analysis Diagnostic Instrument (QADI) (Tan et al, 2002) was used in this study, and the four items that are related to this topic of this paper are given in the Appendix. The QADI was administered to 915 Grade 10 students from 11 secondary schools. Sixty percent were females and forty percent were males.

In addition, twelve other students were interviewed using the QADI as the interview protocol to determine whether the students had difficulty understanding the wording of the items in the QADI, and to probe deeper into the thinking behind their answers.

Results and discussion

The results of the Grade 10 students on the QADI are given in Figure 1. The students found the QADI difficult – the average mark was 5.8 out of a maximum of 19, with 87% scoring 9 marks or less. The reliability of the instrument (Cronbach alpha) is a moderate .68, consistent with the criterion-referenced nature of the test (Ross & Munby, 1991). The focus of this paper is on the Grade 10 students' understanding of the reactions involved in the testing of cations in basic inorganic qualitative analysis. These are ion-exchange reactions resulting in the formation of precipitates and the formation of complex salts when the precipitates react with excess alkali. The students' performance on the relevant items are given in Table 1. Alternative conceptions are considered significant if they existed in at least 10% of the student sample as a higher minimum value, say 25%, would possibly eliminate some valid alternative conceptions from the results (Tan et al., 2002). Data obtained during the development of the QADI, as well as data from interviews using the QADI as the protocol were used to support and illustrate the results obtained from the administration of the QADI.

Table 1 Performance of the Grade 10 students (N=915) on items 1, 2, 13 and 14.

Item	Content option	Reason option				
		(1)	(2)	(3)	(4)	(5)
1	A	0.4	1.6	*24.9*	2.7	-
	B	4.8	7.8	7.1	**40.8***	-
	C	0	5.2	0.8	1.1	-
2	A	*28.6*	*15.7*	5.2	25.7	-
	B	.3	.4	2.7	**19.3***	-
13	A	2.4	4.7	3.2	*11.6*	-
	B	5.8	**44.9***	2.3	4.0	-
	C	*13.0*	1.9	1.2	1.0	-
14	A	4.3	*24.8*	*16.4*	15.5	-
	B	3.0	1.0	2.0	**29.1***	-

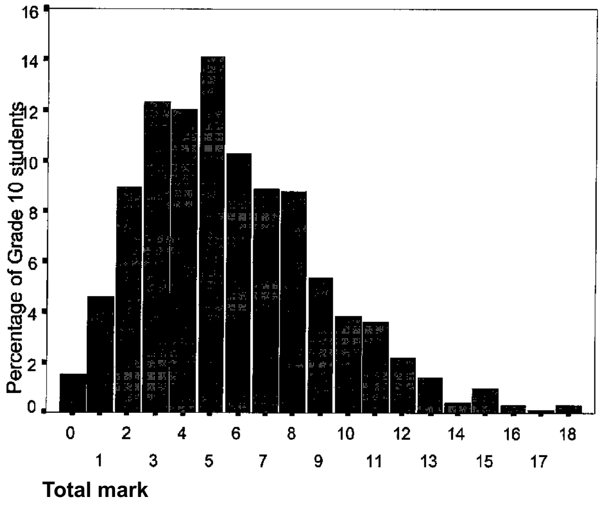

Figure 1 Distribution of Grade 10 students' scores (n=915

Unknown cations are identified in O-level qualitative analysis by reacting them with aqueous sodium hydroxide and/or aqueous ammonia. For example, zinc salt solutions react with aqueous sodium hydroxide to form a white precipitate, zinc hydroxide, which in turn will react with excess aqueous sodium hydroxide to form a colourless solution of sodium zincate, a complex salt. However, in item 1 (see Appendix and Table 1), only 41% of the students knew that the zinc and hydroxide ions combined to form the zinc hydroxide precipitate. Many students indicated that a displacement reaction resulted in the formation of the precipitate because the sodium ion was more reactive than the zinc ion (A3, 25%). This is similar to the finding of Boo (1998), and Boo and Watson (2001) mentioned in the introduction. This showed that students did not understand that the precipitate was the result of an ion exchange reaction, and that in a displacement reaction, a more reactive element displaced the ion of a less reactive element, rather than an ion of a more reactive metal displaced an ion of a less reactive metal. Another possible explanation is that students did not differentiate between the metal and its cation, thus the students believed that the two species had the same properties (Boo & Watson, 2001). In an earlier stage of the study, a free-response instrument, in which students had to write down their reasons for their first-tier options, was administered to a different batch of 203 students. For an item similar to item 1 of the two-tier diagnostic instrument, 21 students (10%) also supplied reasons to the effect that sodium was a more reactive metal than zinc, so it displaced zinc, or that the more reactive sodium ion displaced the zinc ion. These beliefs also appeared in interviews with students as illustrated below by two excerpts of interviews.

> *I: OK...so what actually happens that gives rise to this insoluble substance?*
>
> *S7: What actually happens?*
>
> *S8: Is displacement possible?*
>
> *I: Why do you say that?*
>
> *S8: Because...because sodium is a metal higher in the reactivity series. So er...any cation that is below it may be displaced.*
>
> *I: ...if a precipitate is formed, can you tell me why...or what leads to its formation?*
>
> *S33: Displacement.*
>
> *I: Why displacement?*
>
> *S33: Why displacement...the more reactive one displace the less reactive.*
>
> *S34: Sodium...displaces the...*
>
> *S33: Sodium is very reactive...so it displaces things under it in the reactivity series.*
>
> *I denotes the interviewer, and S7, S8, S33 and S34 denote students.*

The authors believed that the 'more reactive ion displaces a less reactive ion' conception could have resulted from conceptual interference (McDermott, 1988) as well as failure to differentiate the metal from its cation (Boo & Watson, 2001). Students were taught that a more reactive metal displaced a less reactive metal from its compounds in the topic 'Reactivity of Metals', and they also were required to memorize the reactivity series, a list of several metals arranged in order of decreasing reactivity. Thus, what they learned in 'Reactivity of Metals' could have become more prominent compared to what they learned about ion-exchange reactions. This could have caused students to inappropriately apply knowledge from previous learning, that is, reactivity and displacement, to explain ion-exchange reaction. This hypothesis was supported by the following excerpt of an interview with Students 52 and 53.

> *S52: Because…sodium hydroxide will displace the…zinc chloride…cos…the zinc chloride is less stable than sodium chloride…so…a displacement reaction will happen.*
>
> *I: Why did you think of a displacement reaction?*
>
> *S53: We've got the reactivity series…then we learn the displacement…so we apply.*
>
> *I: Why did you think of the reactivity series…is there any reason?*
>
> *S53: We were made to memorise the reactivity series…so it comes naturally.*
>
> *S52: The teacher always stresses the importance of the reactivity series, so the moment you see sodium…you see metals like sodium…any metal from the reactivity series, even though it is an ion, you think of reactivity series right away.*

Item 13 is very similar to item 1 in that an alkali (aqueous ammonia) is added to an aqueous solution of copper(II) sulfate(VI) resulting in the formation of insoluble copper(II) hydroxide. The results showed that 15% of the 915 students indicated in item 13 that a displacement reaction had occurred because copper(II) ion was less reactive than ammonium ion (A4, 12%) or because copper(II) ion was more reactive than the ammonium ion (A3, 3%). However, the ammonium ion does not appear in the reactivity series at all! A possible reason for the alternative conception was that the students concentrated on the copper(II) ion and associated it with copper metal which they knew was low in the reactivity series, and applied their knowledge erroneously. This is illustrated again by the comments of Students 52 and 53.

> *S52: I said…displacement…because the copper ion is less reactive than ammonium ion.*
>
> *I: Is the ammonium ion in the reactivity series?*
>
> *S52: Not really, no.*
>
> *S53: No.*
>
> *I: Then why do you choose that reason.*
>
> *S52: Because a blue solid, so it's like the presence of copper(II) precipitate, there will be copper(II) ions…and furthermore copper is very low down in the reactivity series… easily displaced.*
>
> *I: Why do you think of the reactivity series?*
>
> *S53: The low position [of copper(II)] supports our answer…with the presence of copper…copper(II) ions right, there will be light blue precipitate …so then since copper is so low down the reactivity series, it supports our answer.*

Some clarification has to be made at this point. Displacement is an example of a redox reaction, so option C can be considered to be an umbrella term (Towns & Robinson, 1993) for option A in items 1 and 13. However, in the interviews and in the earlier versions of the diagnostic instrument which required students to write the reasons for their first-tier choices, a vast majority of students only associated the 'reactivity' of the ions with displacement, and the gain/loss of oxygen with redox. The percentages of students choosing option C3 in item 1 (1%), and C3 and C4 in item 13 (2%) also showed that students tended not to consider redox as an umbrella term for displacement. Thus, displacement and redox were retained as first-tier options in items 1 and 13.

The percentages of students choosing the correct answer for item 1 (B4, 41%) and item 13 (B2, 45%) are very similar, but closer inspection of the results showed that only 278 students (30%) had both items correct. Twenty-three students (3%) who had item 1 correct stated that a displacement reaction had occurred in item 13 because of the difference in reactivity of copper(II) and ammonium ion (A3 and A4), while 46 students (5%) who had item 13 correct indicated that in item 1, a displacement reaction had occurred because the sodium ion is more reactive than the zinc ion (A3). These students seemed uncertain that the same type of reaction had occurred in both cases. On the other hand, though 25% in item 1 and 15% in item 13 thought that displacement occurred because of 'difference in reactivity of the ions', only 73 students (8%) consistently indicated so in both questions. The lack of consistency could indicate that the students had several alternative ideas from which students could choose depending on the context (Palmer, 1999; Taber 1999), or that they had little idea of the ion-exchange reactions involved in the testing of cations and resorted to either guessing or on-the-spot thinking.

Another alternative conception was determined in item 13 – a redox reaction had occurred because aqueous ammonia 'gained' oxygen in forming ammonium sulfate(VI) and copper(II) sulfate(VI) 'lost' oxygen in forming copper(II) hydroxide (C1, 13%). As suggested in Tan et al. (2002), the cause of this alternative conception appears to be the use of an inappropriate model, the oxygen model (Garnett & Treagust, 1992). However, a similar option (C2) in item 1 only attracted 5% of the students, with only 14 students (2%) consistently choosing the redox combination in both items 1 and 13. It is also interesting to note that 51 students (6%) who selected the C1 in item, 13, chose A3 (more reactive ion displacing less reactive ion) in item 1. This lack of consistency again showed that students could have either more than one conception of the reaction depending on the context, or had resorted to guessing or on-the-spot thinking.

A further step in the test for cations is to add excess alkali to the precipitate to determine if the precipitate reacts with it to form a complex salt. Hydroxides of zinc, aluminium, lead(II) are amphoteric, and will react with excess aqueous sodium hydroxide to form the zincate, aluminate or plumbite salt, while zinc and copper(II) hydroxide will react with aqueous ammonia to form the respective ammines. The percentages of students getting items 2 and 14 correct are 19% and 29%, respectively, while 125 students (14%) had both items correct. Many students indicated in items 2 and 14 that the precipitate dissolved in, instead of reacted with, the excess alkali because more alkali added meant more space/volume for the precipitate to dissolve (Item 2 - A1, 29%; Item 14 - A2, 25%), or that no new reagent was added and no further reaction except for the disappearance of the precipitate was seen (Item 2 - A2, 16%, Item 14 - A3, 16%). The number of students consistently choosing A1 in item 2 and A2 in item 14 was 154 (17%), while 87 students (10%) consistently chose A2 in item 2 and A3 in item 14. Many students could not relate the disappearance of the precipitate to the formation of the complex salt. This difficulty also surfaced during the interviews.

> *I: OK…is a precipitate insoluble?*
>
> *S12: Yes.*
>
> *S13: Yes.*
>
> *I: Then why should it dissolve in excess?*
>
> *S13: Because before adding excess, that solution perhaps could be concentrated, so…it gives out a precipitate. By adding excess sodium hydroxide, you're giving more volume for the…you're creating more space for precipitate to actually dissolve in it.*

Data from the administration of the free-response test mentioned in an earlier section showed that 108 (51%) of them wrote reasons to the effect that 'no further reaction was seen except the disappearance of the solid', 'a colourless solution was obtained', 'no new products were formed', or 'excess solvent allows more solid to dissolve' to support their answer that the white solid dissolved in excess sodium hydroxide. Thus, the above results seemed to indicate that the students mainly used perceptually-dominated thinking (Ebenezer & Erickson, 1996) – if a solid disappeared in a liquid, then it dissolved in the liquid. In addition, Ribeiro, Pereira and Maskill (1990) reported that if students do not see a new substance being formed, they tended not to refer to the change as a reaction. This problem was further compounded by students being taught to write that the precipitate dissolved in excess reagent, a 'standard' answer required in the examinations to describe the disappearance of the precipitate. When several student were asked why they used the term 'dissolve', they either said that they were taught to do so or that it was given in the datasheet that they used for qualitative analysis practical work. Thus, formal instruction could have caused students to have the idea, in the first instance, that dissolution took place, and perceptually-dominated thinking provided the explanation.

It has to be acknowledged that it is difficult to judge whether the disappearance of a white solid in a colourless liquid involves a reaction or mere dissolution. For example, the addition of sugar to water, and calcium oxide to dilute hydrochloric acid look similar at the macroscopic level, but sugar dissolves in water whereas calcium oxide reacts with the acid. Thus, students needed to know what the substances involved were and if they would react – the Grade 10 students were taught the formation of complex salts though they were not required to write the relevant equations. It could also be argued that at the microscopic level, the formation of the zincate ion is similar to the hydration of zinc ions when zinc salts are dissolved in water, the only differences being the ligands. However, when the solution is evaporated, sodium zincate is recovered and not zinc hydroxide, thus zinc hydroxide should be considered to react with sodium hydroxide rather than dissolve in it.

The authors decided not to consider students stating that a precipitate dissolved in a reagent because it formed a soluble compound with the reagent as an alternative conception (Item 2 – A4, 26%; Item 14 – A4, 16%; A4 in both items, 10%). Though the term 'dissolve' was inappropriate in the situations, the authors believed that the students could have understood what had occurred leading to the disappearance of the precipitate, and agreed with Brosnan (1999) that understanding of the phenomenon in this case was more important than the terms used to categorise the phenomenon. Clerk and Rutherford (2000) also argued that students' alternative understanding of labels should not be considered as alternative conceptions if they understood the concepts involved. In addition, as mentioned early, students were taught to describe the phenomenon as dissolving, so they could have continued to describe it as such even though they understood what had occurred. To consider that the precipitate dissolved in, instead of reacted with, the excess alkali because more alkali added meant more space/volume for the precipitate to dissolve (Item 2 - A1, 29%; Item 14 - A2, 25%), or that no new reagent was added and no further reaction except for the disappearance of the precipitate was seen is a different matter altogether. They did not indicate any understanding of the underlying reaction and hence, had to be considered as alternative conceptions.

Conclusion and caution

The results showed that Grade 10 students had difficulties in understanding the reactions involved in the testing for cations. Many students believed that a more reactive ion displaced a less reactive ion to form a precipitate when aqueous sodium hydroxide or ammonia was added to a salt solution resulting in the formation of a precipitate. This could be because of their 'stronger' learning of the reactivity series and displacement reactions of metals. Many students also believed that the precipitate formed (insoluble hydroxide) dissolved when excess alkali was added because more solvent was added or that no new reagent was added and no further reaction was seen. Perceptually-dominated thinking and the students being taught to describe such a phenomenon as ‘precipitate dissolving in excess alkali’ could be the cause of such alternative conceptions. However, cross-tabulation of the students’ answers showed the lack of consistency of their alternative conceptions. This could be due to students holding several different conceptions and selecting a particular one depending on contextual cues, or having little understanding or thoughts about the reactions and either resorting to guessing or on-the-spot thinking.

The two-tier multiple choice diagnostic instrument on qualitative analysis used in the study was “both an outcome of a research process and an instrument for data collection in that same research venture” (Taber, 2000, p. 471). The instrument was developed from data derived from the first author’s teaching experience and observations of qualitative analysis practical work, literature on student difficulties of chemical concepts related to qualitative analysis, student interviews, and students’ justification of their first-tier choices in the early versions of the diagnostic instrument. Thus, the data from the administration of the diagnostic instrument acted “both to triangulate the interpretation of the existing data base and to broaden the ‘sample size’” (Taber, 2000, p. 471). However, being a pen-and-paper test, it has inherent weaknesses of such tests. For example, students’ language abilities, reading accuracy and interpretation of the items, test-taking ability, sincerity, carelessness, impulsiveness and anxiety could all affect their performance on the diagnostic instrument (Griffard & Wandersee, 2001; Clerk & Rutherford, 2000; Taber, 1999). The content framework which guided the development of the instrument also has to be considered (Hashweh, 1986) by the teacher before administering the instrument. This would prevent the testing of any concept if it was not taught to the students, or if it was not the aim of the course to foster understanding of the concept at the level tested. Using the diagnostic instrument developed for higher grades then it was intended for could be also problematic as students possessing additional knowledge of the concepts tested might be penalised when the additional knowledge causes the distracters to be more plausible to them (Griffard & Wandersee, 2001).

Sanger and Greenbowe (2000) contended that there was no guarantee that students actually had the alternative conceptions indicated by their answers, or that they did not have other alternative conceptions which were not addressed. Taber (1999) cautioned that only the most common alternatives were likely to be diagnosed as the test writer, based on previous research, would have to leave out the less common ones to avoid too many distractors. Voska and Heikkinen (2000) also noted that two-tier tests had the disadvantage of detecting far fewer conceptions than students may actually possess within a content domain and that a multiple choice test in which students had to supply their reasons for their choices could detect more alternative conceptions. They, however, did also acknowledge that the use of such approach within large classes was not feasible, and that the teacher’s analysis and interpretation of results might be fraught with errors without formal training and without the benefit of information from student interviews. Thus, the selection of a multiple choice test with free response justification or a two-tier multiple choice test depends on the goals of the teacher in using the test. An alternative would be to give the option to students to write their reasons if they found that their reasons were not among those given in the second-tier. Students were given the option to do so during the administration of the QADI but less than 3% did so, and many of their reasons corresponded to the less popular ones which were eliminated in the early stages of the development of the diagnostic instrument. Thus, the teacher has to consider his/her goals, the strengths and weakness of such instruments, as well as the content framework of the instruments available before using them in their classes.

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Appendix: Examples of items in the QADI

Experiment A

Step	Test	Observations
a	To a sample of aqueous zinc chloride, add aqueous sodium hydroxide until a change is seen.	*A white solid is obtained.*
b	Add excess of aqueous sodium hydroxide to the mixture from (a).	*White solid disappears in excess reagent to give a colourless solution.*

1. What happens when aqueous sodium hydroxide is added to aqueous zinc chloride resulting in the white solid?

A Displacement
B Precipitation
C Redox

Reason/Justification

(1) The solution is too concentrated with sodium chloride so the sodium chloride comes out of the solution as a solid.
(2) Sodium hydroxide loses oxygen in forming sodium chloride and zinc chloride gains oxygen in forming zinc hydroxide.
(3) Sodium ion is more reactive than zinc ion.
(4) Zinc ions combine with the hydroxide ions.

2. In step (b), a colourless solution is obtained because the white solid _____ the excess sodium hydroxide.

A dissolves in
B reacts with

Reason/Justification

(1) More solvent is added so there is more space for the white solid to dissolve.
(2) No further reaction is seen except for the disappearance of the white solid, and no new reagent is added.
(3) Sodium ion displaces the cation from the white solid.
(4) The white solid forms a new soluble compound with the excess sodium hydroxide.

Experiment C

Step	Test	Observations
a	To a sample of aqueous copper (II) sulfate(VI), add aqueous ammonia until a change is seen.	*A light blue solid is obtained.*
b	Add excess of aqueous ammonia to the mixture from (a).	*Light blue solid disappears in excess aqueous ammonia solution.*

13. What happens when aqueous ammonia is added to aqueous copper (II) sulfate(VI) in step (a)?

A Displacement
B Precipitation
C Redox

Reason/Justification

(1) Aqueous ammonia gains oxygen in forming ammonium sulfate(VI) but copper (II) sulfate(VI) loses oxygen in forming copper (II) hydroxide.
(2) Copper (II) ions combine with the hydroxide ions.
(3) Copper (II) ion is more reactive than ammonium ion.
(4) Copper (II) ion is less reactive than the ammonium ion.

14. In step (b), why does the light blue solid disappear?

A It dissolves in aqueous ammonia.
B It reacts with aqueous ammonia.

Reason/Justification

(1) Ammonium ion displaces the cation from the light blue solid.
(2) More solvent is added so there is more volume for the light blue solid to dissolve in.
(3) No further reaction is seen except for the disappearance of the light blue solid, and no new reagent is added.
(4) There is a chemical reaction between the light blue solid and excess ammonia forming product(s) which is/are soluble

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Preservice science teachers' conceptions of pH

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Abstract:
This study evaluated the pre-service teachers' conceptions of pH, acid, base and neutral. The subjects of this study were 48 second- and third-year science students enrolled in B.Sc.Ed. Programme at Universiti Brunei Darussalam. The results of this study showed that though students thought these concepts were easy, their understandings of the concepts were not at an acceptable level. Most of them were not aware of the conditions and contexts under which these concepts need to be defined. About 46% of the students reported that the minimum value of pH for an acid is one, and 92% reported 14 as the maximum value of pH for a base. The "neutral" concept seems to confuse the students despite their belief that they know it. 75% of the students defined the concept neutral in terms of pH 7, without specifying dilute solutions under standard temperature and pressure conditions. About 15% of the students thought water could be neutral at pH other than 7 due to contamination. Further research is recommended into the students' conceptions of the meaning of concepts and how these change over time.

Introduction

According to the Nobel Laureate, Rabindra Nath Tagore, teachers can never truly teach unless they are still learning as well. It has been reported that effective learning involves linking new knowledge to prior knowledge of students (Bodner, 1988; Hewson & Hewson, 1992). There is a wide range, varying from acceptable through less-acceptable to unacceptable, in students' preconceptions of a concept that influence linking of new knowledge to their prior knowledge and hence their learning (Dhindsa, 2000; Harrison, Grayson, & Treagust, 1999; Pfundt & Duit, 1994). The various types of preconceptions have been associated with various levels (higher or lower) of understanding of a concept. Origins of unacceptable conceptions have been researched extensively (Dzama and Osborne, 1999; Peacock, 1995). The preconceptions of students vary in perceived meaning of the simpler concepts used to define the targeted concept as well as in context (Cassels & Johnstone, 1983; Rodrigues, 1999). An extensive body of research (theoretical and classroom) has been reported in developing conceptual change learning models that address students' less-acceptable and unacceptable views (Duit, Goldberg & Niedderer, 1992; Harrison et al., 1999).

The identification of the preconceptions, however, precedes the treatment. Although various methods, including objective type tests, interviews, and flow maps for identifying students' preconceptions have been proposed, all these methods have limitations (Anderson & Demetrius, 1993; Bar & Galili, 1994; Lee, Eichinger, Anderson, & Berkheimer, 1993; Wenzel & Roth, 1998). A major problem with objective type of tests and interviews in identifying preconceptions is that the questions in them direct the students' thinking towards the examiners' point of view. The others are time consuming and labour intensive, therefore, not efficient for collecting data on large samples. The latest development shows that students' own statements rather than expert guided statements should be used to evaluate students' points of views (Aikenhead & Ryan, 1992). Schmidt (1991) used multiple-choice questions and asked the students to describe reason(s) for their decision. This method is still efficient and preferred way of collecting large volumes of data quickly, though its limitation is language. Students with language deficiencies often cannot explain their logic in making a decision. Conceptual Understanding Mapping (Doig, 1995) and Structure of Observed Learning Outcome (SOLO) taxonomy (Levins 1997) methods have been used to analyse students' preconceptions. However, classification of students' conceptions as acceptable and unacceptable is easy because it does not require extensive training, and is more meaningful for the purpose of addressing them in a lesson plan.

It has been reported from different countries that many high school students', adults', and teachers' conceptions of chemistry concepts differ from mostly accepted point of view (Dhindsa, 2000; Kesidou & Duit, 1993; Lewis & Linn 1994). The pH is an important concept which is introduced to chemistry students at secondary school level. It has been reported in literature that students from many countries have problems in understanding pH and related concepts (Cros, 1988; Hawkes, 1994; Kolb, 1979; Nakhleh & Krajcik 1994; Ross & Munby, 1991; Schmidt, 1991). Cros (1988) reported that students' conceptions of pH and related concepts improved from secondary school to second-year university, but many students were still far below the expected level of understanding. Nakhleh and Krajcik (1994) demonstrated that the use of technology in teaching can help to improve understanding of the pH and related concepts. After inquiring from science students and school teachers, the way pH, neutral, hydrogen ion concentration and other related concepts are taught in Brunei, it was felt that though the students and teachers feel the concepts are easy to teach and learn, the students would not develop clear conceptions of the concepts. There was no evidence of any similar work completed with third and fourth year science students especially in Brunei Darussalam. Since the teaching/learning process is a cultural activity and teachers from different cultures have been reported to explain scientific concepts traditionally, it was therefore decided to evaluate Bruneian pre-service science teachers' conceptions of pH and related concepts.

Objectives

The aims of this study were to evaluate and analyse pre-service science teachers' conceptions on pH, acid, base and neutral concepts in the light of what they had been learned at O-, A- and pre-university levels and what they were expected to know as future teachers of chemistry.

Textbooks Content Analysis and Expected Learning Outcomes

Standard textbooks including prescribed for O-level, A-level, and First-year university students in Brunei were analysed in order to investigate the quantity and quality of pH-related information students were required to learn at various levels. The syllabuses for these classes were also consulted. The chemistry content reported in the textbooks is discussed under three different headings in the following paragraphs.

Textbooks Content Analysis

O-Level Chemistry textbooks by Heyworth (1995) and Prescott (1998) were analysed. The books provided very basic information mostly related to water. pH is described as pH scale: (a) to measure strength of an acid or a base, (b) to show whether a solution is acidic or basic, and (c) to represent power of Hydrogen. Range of pH is given as 0–14. Solutions with pH less than 7, greater than 7 and equal to 7 are described as acids, bases and neutrals respectively.

The A-Level Chemistry textbook by Briggs (1998) was evaluated. In addition to the above information, the books for A-level have discussed pH as a convenient way of representing hydrogen ion concentration ($[H^+]$) of dilute aqueous solutions. The mathematical formula to compute pH ($pH = -\log([H^+])$) is given. Conditions for pH of aqueous solutions are defined. A change in $[H^+]$ with an increase or a decrease in $[OH^-]$ or vice versa are also discussed. Effects of temperature on dissociation and on pH of a solution are discussed. Acid, base and neutral concepts are discussed in terms of $[H+] > (<, =) [OH-]$ respectively.

First-year Chemistry textbooks analysed were Brady and Holum (1996), Brown, LeMay and Bursten (1997), Ebbing (1996), Umland and Bellama (1996), Whitten, Davis, and Peck (1996). In addition to the above information, historical perspective such as follows has been added: "The Danish biochemist S.P.L. Sorensen (1868-1939) devised the pH scale while working on brewing beer." The pH value has been inversely related to the strength of an acid. The temperature and pressure conditions have been stated to define neutral. Umland and Bellama (1996) used examples to demonstrate that the pH can be negative that is less than zero as well as more than 14, but mostly pH is applied to the solutions with $[H^+]$ less than or equal to 1.0 M. Whitten, Davis and Peck (1996) reported the range of pH from –1 to 15 with arrows going outward both sides. The effect of temperature on pH has been discussed in books with pH changing form 0^oC to super heated water. The textbooks did not discuss the effect of pressure on pH, but it was mentioned that super heated water could only be obtained under pressure. In the textbooks, the authors referred to dilute solution without defining the meanings of this concept. Moreover, they did touch the activity of H^+ rather than concentration, but it was not associated with pH.

Expected Learning Outcomes

It seems reasonable, then, to expect third- and fourth-year science students to be able to defined pH in terms of Hydrogen ion concentration, an acid as substance with $pH < 7$, and a base as a substance with $pH > 7$ under standard temperature and pressure conditions. The lower limits of pH for dilute aqueous acidic (1.0 M) solutions is zero, but for concentrated acid solutions may be lower than zero (negative). Similarly, pH for a dilute aqueous basic solution is 14, but for concentrated basic solutions it may be higher than 14. The pH is influenced by temperature not pressure. Moreover, hydrogen ion and hydroxide ion concentrations are equal in neutral solutions. If they are using water as example, they should state the standard temperature and pressure conditions.

Method

Sample

The subjects of this study were 48 third and fourth year science students enrolled during 2000 in the Bachelor of Science Education degree programme at Universiti Brunei Darussalam. The sample consisted of 53.3% of the population consisting of second and third year science students enrolled at the Faculty of Science, Universiti Brunei Darussalam. Male to female ratio in the sample was 1:3. The admission to the degree program required them to have passed at least 2 A level subjects in science or non-science. Moreover, all the students had studied integrated science for three years.

Instrument, Procedure and Scoring

The instrument used in this study consisted of 8 questions of which first 6 were of short answer type and questions 7-8 were of yes/no type. The eighth question was divided into two parts both yes/no types, whereas question 7 required the students to reason out their yes/no responses. Similar procedures have been used by other researchers (see Schmidt, 1991). The descriptions of the questions are given in Tables 1 to 6. The students were informed that this was not an examination and would not count towards their final assessment. Participation was voluntary. The instrument was given to the students in their classes and enough time was allowed for them to answer the questions. The students' responses were scored as acceptable, less acceptable and unacceptable.

Results and Discussion

Understanding of pH

pH is an alternative method of representing hydrogen ion concentration ($[H^+]$) of a solution and was originally applied to a very dilute solutions ($[H^+]$ less than or equal to 1.0 M). Pre-service science teachers' conceptions of the concept are demonstrated in Table 1. 16.7% of the students' understanding of the concept appears to match with the acceptable definition. However, 50.0% students reported it as a measure of acidity of a solution. These students do possess some understanding of the concept, but their understanding is lower level. In a study reported by Cros (1988), 17% first-year and 13% second-year chemistry students gave similar descriptive definition for pH. However, in this study the percentage of students giving descriptive definition was much higher than reported by Cros (1988) for first- and second-year French students, despite subject of the present study were third and fourth year students. The conceptions of the concept of about one-third of the students was at very low level. This data was comparable to data reported by Cros (1988). In one of the misconception over 10% students understood pH means the concentration of an acid or a base. It has been known that students do confuse concentration and strength of an acid or a base (Ross & Munby, 1991). These results also show that students also think pH as the concentration of an acid or a base, because the concentration of an acid may not be the same as its $[H^+]$ especially of other than monoprotic acids. The studies reported by Ross and Munby (1991), and Cros (1988) demonstrated that students' conception of pH improved from descriptive to scientifically accepted from school (grade 11) to university (second year). However, in this study most of the university students provided the descriptive definition of pH. The above results show that although a majority of students appeared to know the concept pH, in fact, their understanding of the concept was at lower level than was acceptable.

Table 1 Students' understanding of pH: Description with percentages (n = 48)

Student Number	Description of Students' Responses	Number of Students (%)
1.	Measure of $[H^+]$	16.7
2.	Measure of acidity and basicity	50.0
3.	A method (indicator/test) to measure acidity and basicity	4.2
4.	Scale of acidity	6.2
5.	Concentration of acid or base	10.4
6.	Range of acidity	6.2
7.	Others	6.2

Acid and Base in Terms of pH

Table 2 shows that 37.5% students were able to define an acid in terms of pH correctly. 12.5 % of the students defined acid as substance with pH between 0–7. This response appears to show that students have limited understanding about the limits of the pH scale for dilute acids only. Brown, Lemay and Bursten (1997) claimed that pH value of a solution, in principle, can be less than zero or greater that 14. The remaining 50% students had misconceptions about the concept.

However, when they were asked about the lowest value of pH for an acid, none of the students demonstrated acceptable conception of the concept. It was surprising to note that 45.8% of the students thought that the lowest value of pH of an acid was 1.0. Table 2 also shows that 37.5% of the students who appeared to have demonstrated understanding that acid is a substance with pH < 7, were also not clear of the pH range for an acid. Personal discussion with some selected students revealed that the students have difficulty in viewing continuity between numbers. For example, a student reported that pH 7 is neutral, therefore, an acid has to have pH less than or equal to 6. Cros (1988) also reported that 5% for university students as compared to 23 % of secondary students from France defined acid in terms of pH when they were not restricted to define acid in terms of pH.

Table 2 Description, and percentages of subjects' responses in reference to their understanding of acid in terms of pH and the lowest value of pH for an acid (n = 48)

Student	*An acid in terms of pH is:*		*Lowest value of pH for an acid is:*	
Number	pH	%	pH	%
1	< 7	37.5	0	18.8
2	0–7	12.5	0.01	12.5
3	1–6.9	22.9	1	45.8
4	1–6	14.6	1-3	2.1
5	0–6	2.1	6-7	14.6
6	Others	10.4	6	6.2

Table 3 shows data on students' attempts to define a base in terms of pH. Of the students, 45.8 % reported that base as a substance which has pH > 7.

Table 3 Description and percentages of subjects' responses (their understanding of a base in terms of pH and the highest value of pH for a base) (n = 48)

Student	*A base in terms of pH is:*		*Highest value of pH for a base is:*	
Number	pH	%	pH	%
1	>7	45.8	14	91.6
2	7–14	25.0	13	2.1
3	7–13	2.1	13-14	4.2
4	8–14	18.8	9	2.1
5	Others	8.3	-	-

These data suggest that the students might have an acceptable conception of the concept. The percentage of these students was slightly higher than to those who defined acid as substance with pH< 7 (Table 2). 25.0% reported that a substance is a base if its pH is in the range of 7 to 14, which match with the descriptive definition of pH of dilute basic solutions only. The remaining 29.2% students had misconceptions about the concept with 18.8% reporting that range of pH for a base is 8–14.

However, when the students were asked to report the highest value of pH for a base, none of the student reported it to be > 14. The first year chemistry textbooks show the extended range of pH beyond 0–14 of acids and bases (Brady & Holum, 1996; Whitten, Davis, & Peck, 1996), but students had not acquired the concept.

Unlike data in Table 2 for an acid, there was a complete agreement among the students (91.6 %) that highest value of pH for a base is 14, which is for a basic solution of 1.0 M $[OH^-]$ under standard temperature and pressure conditions. Only one student was confused who reported pH of 9 as the highest value of pH for a base. The data in Tables 2 and 3 demonstrate that students were not able to apply their knowledge and understanding of concept pH to define an acid or a base correctly. The data in Tables 2 and 3 also demonstrate that the percentage of students who defined acid as pH <7 and base as pH > 7 were comparable. However, literature shows that more students have problems in dealing with bases than acids (Cros, 1988; Ross & Munby, 1991).

Table 4 Description, and percentages of subjects' understanding of the "neutral" concept

Student Number	Description	Responses (Percentage)
1	$[H^+] = [OH^-]$	8.3
2	Neither acid nor base	16.7
3	pH 7	75.0

Understanding of "Neutral" Concept

The most acceptable definition of the concept "neutral," in acid base chemistry, is a solution in which the concentrations of hydrogen ion ($[H^+]$) and hydroxide ion ($[OH^-]$) are equal. It was surprising to note data from Table 4 that only 8.3% of the students' conceptions of the concept was at an acceptable level despite the concept having been introduced at O-level (grade 10). O-level texts clearly state that 'neutral solution contains an equal number of hydrogen ions and hydroxide ions (Heyworth, 1995). The remaining 91.7% of the students had misconceptions about the term neutral. For 16.7% students, neutral meant no acid or base which appears to match with the conception of some German students who believed that ($[H^+]$) and ($[OH^-]$) react completely and thus neutralize each other (Schmidt, 1991). The data also showed that 75.0% of the students' conceptions of the concept neutral was limited to neutrality of water under standard temperature and pressure conditions, but none of them reported these conditions. To explore further understanding of the concept, students were asked if water can be neutral at a pH other than 7.

Table 5 Description and percentages of subjects' understanding of concept "neutrality of water" (n = 48)

Question	Can water be neutral at a pH other than 7?		
Response %	Yes 20.8 %	No 58.4 %	Others 20.8 %
Reason	Depends upon temperature & pressure (2.1 %)	pH<7 an acid, pH > 7 a base (35.4 %)	Idon't know (2.1 %)
	Due to contamination (14.6 %)	Neutral water has pH 7 only (16.7 %)	No reasons given (18.7 %)
	Range of neutralization (4.2 %)	At pH 7 no H+ or OH- exists (2.1 %)	
		pH of water does no change (2.1 %)	
		Water is tasteless (2.1 %)	

The data in Table 5 show that only 20.8% of the students appeared to have acceptable conceptions of the concept and remaining 79.2% did not. 35.4% reported that water can be only neutral at pH 7.0, otherwise it is will be acidic or basic. Only 2.1% students knew that pH of water is temperature dependent, whereas 16.7% thought that water can be neutral at pH other than 7 because of some contamination in it. These results demonstrated that the concept neutral in acid base chemistry is not well understood by the students. Schmidt (1991) argued that the concept "neutral" has an ambiguous meaning in chemistry and chemists use it in different contexts, e.g. neutral complexes, neutral ligands and neutral acid. In these contexts, the word suggests that these particles carry no charge. Similarly, in Physics electrically neutral means there are neither + nor – charges. These concepts seems to confuse students in identifying different meaning of neutral in acid base chemistry, and students appear to translate their understanding of neutral concept in other contexts to define in acid base context.

Effect of Temperature and Pressure on pH

pH is temperature dependent and it decreases with an increase in temperature because an increase in temperature increases ionization. For example, the concentration of hydrogen ions ($[H^+]$) in water at 25^{o} C is 1.0 x 10^{-7} M., whereas at 50^{o} C and 100 ^{o}C it increases to 2.35 x 10^{-7} M and 7.42 x 10^{-7} M respectively. The electrical conductivity of water at 50^{o} C is amore than 3 times the conductivity at 25^{o} C. Moreover, the pure water becomes highly conductive at critical temperature. The effect of temperature on pH has been clearly stated in standard first-year and in some A-level Chemistry books (Briggs, 1998; Brown, LeMey & Bursten, 1997), but students have not understood the concept. Although, the ionization of a solution is not influenced by pressure, however, pressure helps to attain temperature above boiling point for a liquid or a solution. For example, the critical temperature of 374^{o} C for water can only be attained in the presence of high pressure of 22.1 MPa (Aylward & Findlay, 1994). Data on question 8 (not tabulated) also supported that most of the students' conceptions about the effect of temperature and pressure on the pH of a solution were not adequate.

Implications

When a new chemical concept is formed, chemists try to find a term that points to the meaning of the concept. With the dynamic nature of science, however, the meaning of a concept can change to the extent that original definition turns out to be misleading. For example, neutral during 19th century, a substance was classified as neutral if it was neither acidic nor basic (original definition). However, we now define it as a solution in which $[H^+] = [OH^-]$. Teaching original definition of a concept in lower grades to simplify the concept for teaching may create problems in getting modified over time. It is well known that as students go to higher grade their concepts have to be modified. The modifications of concepts have been reported to occur through a process of Learn, Unlearn and Relearn. The teachers are involved in the process of Teach, Un-teach and Re-teach. Un-teach and Unlearn processes are very difficult. It is important that teachers who are teaching difficult concepts at lower grades should put emphasis on attached conditions. Otherwise, the concepts are learned in isolated situations and their meanings in higher grades do not match with the scientifically accepted meanings. Numerous examples could be quoted, but let us say teaching acid as substance with pH less than 7 without defining temperature conditions makes it difficult for students to modify the concept at later stage. Moreover, without defining temperature and pressure conditions, it may be impossible to say that a solution with pH 6.5 is acidic or neutral. Moreover, the information presented in books is out of context. Many books present information without referring to the conditions. Committees recommending books for a grade should consist of content experts and teachers.

While teaching at lower grades, teachers should emphasise the conditions and exceptions. For example while teaching the range of pH 0–14, the condition for only dilute solutions (1.0 M) at 25 °C should be emphasized. Although, the aims of university teaching are justifiably ambitious to ensure a better acquisition of important notions by students, this study suggests that this objective is far from being achieved. One can feel the impact of this level of content knowledge of the perspective teachers on future students. There is ample research on how to use students' preconceptions to modify them to scientifically accepted conceptions. The university- and school-teachers should use the educational research findings to improve the teaching. Moreover, university and school-teachers should support each other. The university staff should hold workshops to demonstrate the teachers how different concepts have got modified over time and in turn they will receive help from school teachers who will direct their teaching towards modified meaning of the concept.

This study demonstrates that the pre-service teachers' knowledge of the chemistry concepts is not up to the expected level. This is also true of Biology (Yong, 1999), Physics (Tan, 1998) and Geography (Upex, 2000). Students and teachers should realize the inherent difficulty attached in learning the concepts. More research in local context is needed to identify the concepts that need special attention. Research in Brunei on how the students' conceptions of scientific concepts are modified over time (school to university) is also recommended.

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Critical Review

The periodic kingdom, 1995

P. Atkins

Abstract

Imagine flying over a magical place, you look down and see a glittering land of silver and gold hues with lakes of red and molten silver. As the rain falls some parts of the land fizz and bubble whilst others violently explode. Towering mountains and sharp cliffs contour the land. This is the world of the periodic kingdom, a book written by Peter Atkins which allows for visualization of the many characteristics of the elements and contains many useful ways of teaching the organization and reasoning behind the layout of the periodic table.

Introduction

The Periodic Kingdom relays information of the periodic table almost as a fictional story-land such as Narnia in the story of The Lion, the Witch and the Wardrobe. The Periodic Kingdom allows for the visualization of the periodic table of elements as analogous to the Earth. It consists of regions of elements that are in geographical areas. Regions have alliances with neighbors similar to countries due to similar characteristics just as neighboring countries have cultural and religious ties.

Each region produces goods, as do countries, depending on the richness of the land. The richness of the land also gives the land a distinct look, which can be visualized. Some areas are too dangerous for inhabitants due to the features of the land. Each region also has a history of how and when they were discovered. These regions have laws and governments controlling their behavior. The land also has contours of cliffs and plateaus dependent on the mass, diameter and density which are illustrated for further understanding.

As the reader flies over or walks through the land, features are observed and patterns of continuity are seen which helps explain the reasoning behind the layout of the periodic table. As we read of the history of discovery it can be seen how the mapping of the land allowed for subsequent discoveries of unknown lands and an insight of the probable properties and areas of where unknown lands may lie.

Throughout the book a similar language is used that helps to create the visualization of the kingdom and better interpret the story. The language is not that obscure from the reality of the periodic table, which helps the reader to avoid a continual comparison of the table and the kingdom.

During your travels you are given a descriptive account of the uses of many elements and many interesting points such as the estimation of only 17 Francium atoms on Earth. The foundations of naming is also repeatedly highlighted in the book which not only adds interest but gives a greater understanding behind many ambiguous names.

The book is written without any presumption of prior knowledge of chemistry. Analogies and visualization will always increase interest and therefore retention making the book an excellent instrument in lower school introductory chemistry courses.

The Terrain

The first chapter on the terrain gives a visual picture of where metals, liquids and gases are found on the periodic table. To make this useful in an introductory course on the periodic table, students could color a periodic table in the regions as the teacher talks about the properties of the areas as described in the second chapter on products. The Western Desert, for example could be colored a grey color to represent the metals found in this region. The Lake of Bromine could be colored red for the color it looks at room temperature and the lake of mercury silver.

This chapter also will be useful in describing how similar elements are found in groups. This will be uncovered as the students color their tables to reveal the groupings of the elements. Another important chemistry concept of allotropes is touched on during this chapter, which is described by a useful analogy as the seasons of a particular element.

The Products

The second chapter describes the products of the elements that are explained one area at a time to highlight again the similarities of the areas of the periodic table. This chapter would be best described to students alongside chapter one so students can further visualize these relationships. The usefulness of the elements in relation to the characteristics is highlighted such as the most reactive areas being least useful and metals such as gold being unreactive and resistant to corrosion therefore useful.

The order of discovery is explained as those easiest to extract from their ore such as iron were therefore discovered first. This kind of information may not be required by the curriculum but as always helps further student understanding and therefore aid interest and retention. Another interesting point was that the Western Desert was exploited from east to west for example copper was displaced by iron. It is also pointed out that as society became more equipped with each new discovery it allowed for more exploration.

Alliances of neighboring elements such as in the formation of steel in making alloys is compared to alliances between nations due to similar characteristics. This is an excellent analogy for students to understand the concept of alloys. The importance of some unlikely substances is also explained here such as the use of nitrogen in protein synthesis and formation of DNA. Students will often think that the most important substances are the metals and also fail to see the link between chemistry and other sciences such as biology so this information given in a chemistry class will hopefully shed some light.

Another useful trend found in the periodic table is the increasing reactivity from north to south. Reactivity is explained in a most exciting way as what happens when rain falls in this region. The mental pictures of the earth bubbling and fizzing and having explosive reactions will be well received with students. Although it is pointed out that the more reactive a substance the less its uses, some of the uses of these substances are highlighted such as the use of radium in cancer treatment.

Geography

The changes in properties of the regions are shown as altitude for visualization and to show the continuity of the periodic kingdom. Mass is shown to slope up north to south and west to east although some faults are shown which may "trip a traveler." Diameter is shown to have a loose rise from north to south and drops in the isthmus. It is explained that the lack of a strong pattern indicates the fact that diameter is not a fundamental property of elements. Density is explained as a factor effected by mass and diameter and the relationship can be seen when comparing the diagrams of altitude. Ionization shows a rise from west to east and a decrease from north to south. The relationship of ionization can be compared with the diameter such as cesium being larger so electron extraction being easier. The Eastern rectangle is seen much higher in ionization therefore less reactive due to the decrease in diameter. The western desert is low in ionization therefore the metals here are very conductive.

The diagrams and explanations of this chapter should again show valuable relationships of mass, diameter and density and then diameter and ionization giving a clearer picture of the arrangement of the table and the reasoning behind it.

History of Discovery

The most interesting point made by this chapter is that most discoveries have occurred by investigation rather than chance. The ways in which discoveries were/are made such as spectroscopy, electrolysis and chromatography are explained in detail with examples of element discovery. I found the age of use of these techniques for discovery most fascinating such as the use of electrolysis in the 19th century to discover potassium in 1807. This technique sounds and looks like a technique surely only possible in the 20th or 21st century. I am sure students will also find this information credulous.

The periodic kingdom suggests where new regions should be so as explorers can plan their search. The characteristics of neighboring regions can be used to predict new regions. This is highlighted by the discovery of argon, the first noble gas. The rest of the noble gases were then quickly discovered as the dip in reactivity was unexpected next to the cliffs.

The importance of the Manhatten project in the 1940s said to be a giant reclamation project is explained. Students will find it interesting to find that the race for nuclear weapons lead to an amazing array of new elements that we would otherwise be unaware of. During the Manhatten project many new elements were actually synthesized from throwing atoms against others to see if they would fuse for a fraction of a second.

The undiscovered Atlantis in the south and the possible discovery by future Columbus' will give students an imaginative insight into the future of the periodic kingdom.

Naming of Regions

Naming is often an area of science overlooked as unnecessary to elaborate on. I find students more likely to remember words and their spelling if they have an understanding of where the names came from. This area of the book explains how the naming of elements has come from either properties of the element such as color or smell, countries and cities, names of scientists or names of gods. Some examples are Copper from the Latin cuprum – Cyprus where it was found, Calcium from the Latin clax meaning lime where calcium is found, Iodine from the Greek ioeides meaning violet for its color, Bromine from the Greek bromos for stench due to its odour, Dysprosium from the Greek work dysprositos meaning hard to get at for obvious reasons, Valence from the Latin valete for strength and many more.

Origin of the Land

This chapter of how elements first came about in the universe will be useful for astronomy as well as chemistry courses. It explains how hydrogen was the first element formed by the big bang and then how stars produced helium from nuclear fusion then explains how due to the fusing of various combinations each new element was formed.

The Cartographers

The chapter on the mapping of the periodic table is an area of science usually forgotten as we seldom talk of historical discoverers in lessons unless it is Newton. I found this section most interesting and think it is important for students to see how scientists don't always discover substances but sometimes put patterns and trends together which is just as important. If this was not done future discoveries would be very hard. During scientific investigations we teach students to look for patterns and relationships in their data and here we see the importance of finding those relationships.

Newlands saw elements in octaves with every eighth element in order of weight having harmony (with no noble gases discovered at this stage). Odling mapped regions close to what it is today with some missing regions important for discovery of new elements. Meyer plotted atomic weights against volumes in a graph, which showed peaks at 8, 16 then 18 which became useful information leading to valency. Mendeleev used atomic weights only showing similarity of elements from north to south and blends of properties from east to west aiding the reasoning of the properties of elements.

It is explained that there is still debate in the layout of the periodic table that is now mapped by atomic number rather than weight but maybe in the future with the aid of new technology a better visual display may be made.

The Laws

The properties of atoms are due to the atomic number being the same as the electron number of an atom. It is the number of electrons that determine the characteristics of an element and the elements are placed in blocks due to the arrangement of the electrons (orbitals). It is found that when orbitals are filled the atom is in its lowest energy state. Students will be able to see how elements are arranged in the periodic kingdom due to the type of electron distribution with the western rectangle having no nodal plane, the eastern rectangle having one nodal plane, the isthmus having two nodal planes and the southern island having three nodal planes.

The next point of organization in the table is the group number indicating the amount of electrons in the outermost orbital. The periods can then be discussed indicating the rank of the orbital in the outermost of the atom.

Chapter 10 discusses ionization and why it occurs. An analogy is made between chemistry and democracy with two parties competing as in atomic diameter competing with expansion due to electron-electron repulsion and contraction due to electron-proton attraction making observations hard to predict. Again relationships of neighbors in the kingdom are highlighted due to similar characteristics. As electrons are shielded in some arrangements such as those in the southern island it is more likely for contraction to occur as electrons are repulsed from each other. This block therefore plateaus in diameter. This also explains the high density in this area.

The likelihood of ionization is discussed, as electrons are closer to the nucleus the energy for ionization increases and therefore is less likely. The importance of groups showing what charges are formed by elements is important for students when first discussing valency and formation of compounds.

Alliances

In years nine and ten, students learn how to write chemical formula. The reasoning behind the formation of certain compounds is often lost in the rush of teaching how to write formula. I think the inclusion of the mechanics of formation is just as important and should be explained as it will eventually lead to students understanding the formula rather that just unconsciously writing formula. Most teachers would explain the difference between ionic and covalent bonds and the differences between the product's properties such as melting point and strength. The reasoning behind the properties is the area often neglected and this information will be quite useful in student understanding such as the ionic solids making a tight structure that needs to be shaken vigorously to shake them loose therefore have a high melting point.

This chapter also explains how elements from same groups form compounds similarly allowing again for students to see the importance of the layout of the periodic table.

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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**
- **News about people or places**
- **Forthcoming events**
- **Books to review**

Critical Review

Chemistry in the Marketplace (5th edition)

Ben Selinger

Chemistry in the Marketplace by Ben Selinger is a book which seeks to inform consumers about the chemistry they encounter in their daily lives. The information contained within the book has been broken up into areas such as chemistry in the dining room, the laundry and in the medicine cabinet. Within these chapters, the book covers a variety of topics with something of interest to everyone. The diversity of topics which the book covers includes baby care, cosmetics, alcoholic products and art forgery detection.

An issue which was raised by Selinger in the book concerned controversy over phosphates in detergents. It has been believed that the phosphates in the detergents cause algal growth in water ways. Due to this, many countries set limits on the amount of phosphates in household detergents. However, according to Selinger, it is not the phosphates which are causing the environmental problems in the water ways but rather the total amount of detergent used and the level of pollution in the water way. Selinger supports this with the fact that unpolluted lakes will absorb a large amount of phosphates through the action of zooplankton eating the algae which are then in turn eaten by the fish.

A second issue raised by Selinger in his book involves the effect the hole in the ozone layer has on the incidence of skin cancer. Selinger states that the disappearing ozone layer is not responsible for the increase in skin cancer but was caused by a change in fashion. The change which took place was, while it was once fashionable for people to wear hats on their way to work, this altered in the early 1950's when it became unfashionable to do so. Selinger goes on to state that the best protection from skin cancer involves a constant tan as opposed to binge burning.

The book also discusses some of the more fundamental aspects of chemistry by covering the properties of solids, liquids and gases. However, the book also discusses the fact that it is not strictly true that the particles of liquid crystals are arranged in one or two dimensions, solids in three dimensions and liquids in none. Selinger discusses that liquids will show some order while solids will show some disorders. While the book does cover some of the simpler concepts in chemistry, it also gets quite detailed and heavy going in some parts. For example, the section on the process of saponification requires a good understanding of chemistry. However, as the book is used as a textbook, it is natural for the writer to assume that the reader has a certain amount of background knowledge.

Selinger also discusses advances made in some areas of chemistry and states that not all is currently known about the topics with research constantly making new developments. An example of this from the text is in the section on hormones used in sport. A brief history of performance enhancing drugs is outlined stating what advantage the drug gave, how long the effects lasted, side effects it caused and how it could be detected. Selinger discusses the latest attempt for some sportspeople to cheat by using Luteinising Hormone to help mask the effects of other drugs and how Luteinising Hormone can be detected by radio-immunoassay. As soon as a method of detection is found, a new way to cheat is discovered which leads Selinger to advise the reader this will be continued in the next edition of the book.

The graphics were generally of a high quality and easy to understand. The photographs in the centre of the book were also interesting to look at although I do not think I would use them a great deal in the classroom. I would use Plate XXIV which shows sources of radiation in the UK as it is both informative and very colourful. Some of the cartoons which appeared in the book were a nice distraction and could be used when introducing a topic.

Another aspect of the book which I liked was the glossary. It contained many of the more technical terms used within the text and would be very beneficial to those without a strong background in chemistry or for those who have forgotten some of the terms.

The appendixes were very detailed and covered some extra information a reader may require such as nomenclature in chemistry starting with the very basic ones like methane to the more difficult toluene and naphthalene. Also covered in the appendixes was some fundamental information on acids and bases including information on neutralisation.

The book also contains some useful information on other branches of science. For example when the chemistry of cosmetics is being discussed and how some are absorbed into the skin, the structure of the skin is also discussed. The diagram which accompanies this section is also very clear and the text very comprehensive. Physics is also covered in the section on ionising radiation which goes into radioactive disintegration and the biological effects of radiation. This allows the reader to associate chemistry with another area of science they may be more familiar with, making it easier to understand.

Some of the sections in the book were quite technical making them, at times, difficult to read. The section on the chemistry of energy was one section that I personally had trouble getting through. This section seemed to lack some of relevance than previous sections had and the tone it was written in also seemed to be more formal. However, this is really the only complaint I have about the book and it is a very minor one at that.

Application in the classroom

I feel that this book has many applications in the science classroom. The book is an excellent reference for teachers, especially those who might not have a strong background in chemistry. It contains many snippets of information teachers can use with all years groups to arouse interest. For example, the section on the origins of the element names was very interesting and could be used when introducing students to the elements and their symbols. I found the story about the naming of amethyst especially interesting and I am sure many students would as well.

The issues raised by Selinger could also form the basis of class discussions or investigations. I think this would be especially interesting to do with the Selinger's belief concerning the incidence of skin cancer and the hole in the ozone layer. A class debate could be another avenue for exploring this topic.

The experiments which have been placed in the margins of the book are often easy to perform and can be used to illustrate a point or to motivate the students and arouse their interest. An example of an experiment which could be used for gaining the attention of students was proving there was iron in breakfast cereal. The activity involved placing water and an iron rich cereal in a Petri dish and moving the cereal using a magnet. I would use a variation of this experiment with students after they had done some work on magnetism. The students would be given a selection of different cereals (and access to the boxes) and using the magnet, they would need to investigate which cereals can be moved using the magnet and why some can be moved but not others.

As Chemistry in the Marketplace is a text book, it could be used to extend the knowledge of high ability chemistry classes. For example, a section of the book which could be used for this purpose is the section on solids and liquids showing some disorder and order respectively.

From the appendixes, I would use the pH scale which contains a number of household items and their pH. I would give the students a blank pH scale and give them the names of the household goods and get them to arrange the names on the scale according to where they think it belongs. I think many of the students would be surprised that Coke has a similar pH to lemon juice and vinegar. The consequences of this could then be explored through a class discussion.

I would also read some of the anecdotes to them such as the one about the Rabbi who was allowed to see the very secret recipe for Coke to ensure that it was Kosher and the changes the company made to their product so the Jewish community could drink Coke. I think that the students would find this quite interesting.

I personally believe that this book would be an excellent reference book for teachers, especially those without a chemistry background. The book would be a great starting point for information and ideas when planning a section of work on chemistry. While I believe I have quite a good knowledge of chemistry, the book certainly gave me some ideas on how to present some of the concepts in chemistry to make it more interesting for the students.

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Reduction of Metal Oxides using Bench Gas

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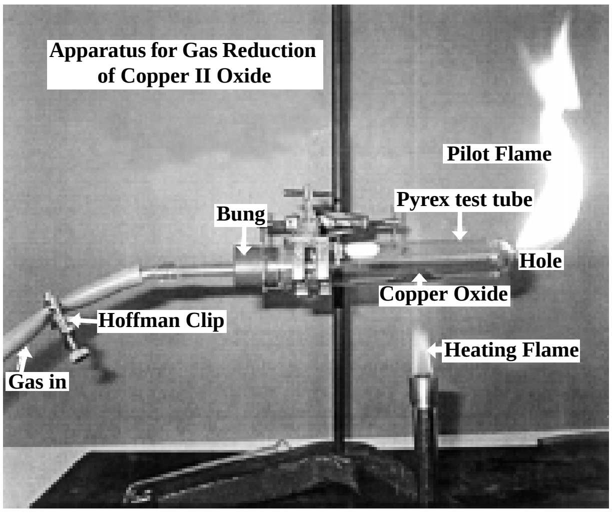
We are all familiar with the trusted reduction of lead oxide to lead using carbon block and blowpipe. It does work quite well but as an industrial method of reduction in Western Australia natural gas is a cheaper and cleaner alternative. The DRI process used in Port Hedland involves the reduction of iron using reformed natural gas (mainly hydrogen and carbon monoxide) obtained from natural gas.

I used to like doing a similar experiment to reduce copper oxide using hydrogen gas in a heated combustion tube. It is not an easy experiment to perform without a gas bottle of hydrogen and a little dangerous with homemade alternatives.

A safe alternative involves the reduction of copper(ll) oxide to copper using bench gas which consists mainly of butane. Bench gas is a good reducing agent, in the classic sense, as it wants to grab oxygen from the metal oxide. (Note although the gas is not reformed it behaves in much the same way.) The reaction has reasonable activation energy so it has to be heated to start with but then as it is exothermic, it proceeds without further heating:

$$C_4H_{10}(g) + 6.5CuO(s) \longrightarrow 6.5Cu(s) + 4CO_2(g) + 5H_2O(g) + \text{heat}$$

I have devised the following apparatus:



The test tube was one made from pyrex. We heated the end in the manual arts department using a fine torch and while red hot pushed a thin welding rod from the inside through the base of the tube.

To limit the gas flow through the tube a Hoffmann clip was placed on the tube leading from the gas tap to the test tube. The unreacted gas is burned at the hole in the end of the test tube.

How to demonstrate the reduction

Step One

Set up the tube as shown in the diagram above. The black copper oxide is carefully placed either loose or in a small porcelain boat at the centre of the test tube. It is not necessary to spread the oxide thinly as the reduction works its way throughout its entire mass.

Step Two

Adjust the gas supply and light the gas at the hole to give a small pilot flame. In the photo, the pilot flame is larger than it needs to be but I was trying to impress a colleague with this demonstration.

Step Three

Gently heat the test tube under the oxide until it starts to glow red. Stop heating and observe the pink colouration spread throughout the black mass.

Step Four

Continue passing the reducing gas over the product. This will maintain a reducing atmosphere thereby preventing reoxidation to copper oxide.

Step Five

After about five minutes shut down the gas supply and examine the pink copper produced.

Teaching points:

1. Bench gas is a reducing agent
2. Redox in terms of oxygen exchange
3. Redox in terms of electron exchange (Cu only)
4. Redox in terms of change in oxidation number (note C is -2 and -3 → +4 so the gas is oxidised and the CuO reduced)
5. Activation energy
6. Exothermic reaction

Conclusion:

I tried the experiment with litharge and it worked very well producing a lot more lead than the classic carbon block experiment.

We next tried iron(III) oxide and no reduction occurred. Either the reformed gas is a stronger oxidising agent than bench gas or the temperature we could achieve with a bunsen burner could not supply the necessary activation energy to kick start the reaction (there would be a greater affinity between Fe and O than between Cu and O and Pb and O).

Avoid experimenting on the metal oxides less active than copper, as they will decompose into the metal anyway on heating.

Good luck!

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All of the materials are suitable for teacher and student use.
The resources available are:

Magazines

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Chemistry Review	Published 4 times per year for the Chemistry Dept, University of York (UK)
CHEM 13 NEWS	Published 9 times per year by the Chemistry Department, University of Waterloo (Canada)
Physics Review	Published 4 times per year for the Physics, Electronics and Education Departments, University of York (UK)
Biological Sciences Review	Published 4 times per year for the School of Biological Sciences, University of Manchester (UK)

CDROMs

ChemMatters CD ROM (version 2. 0)	contains all issues of the magazine from Feb ’83 to Apr ’98
Journal of Chemical Education CD ROM 2000	contains all J Chem Ed issues from 1997 to 2000

Books

Ben Selinger	*Chemistry in the Marketplace* (5th Ed.)
Ben Selinger	*Why the Watermelon won’t Ripen in your Armpit*

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