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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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Contents

* refereed papers

Cover photographs: Delegates at the Chemistry Discipline Network meeting at the ACSME conference in Sydney, September 2012. Photo courtesy of James Mitchell Crow.

In this issue.....

Mitchell Crow, **O'Brien** and **Schultz** report on the 18-month old Chemistry Discipline Network: its establishment, achievements and directions. They report "Enhanced communication within the community of chemistry academics in Australia is already leading to more collaboration on grants, and the more experienced members are sharing their knowledge of publishing in the Scholarship of Teaching and Learning." Which chemist would not link into this network?

As part of the Science and Mathematics network of Australian university science educators (SaMnet), eight teams at universities across Australia are involved in projects that will attempt to change how chemistry is taught. As well as enumerating the key principles of this effort, **Rifkin et al** describe the eight projects. Each is an "action-learning" project, acting to change the teaching in their school, while learning from the experience and learning to lead change. Some of the projects are related to developing new teaching approaches, while others are adapting established approaches in one context to new settings. In its totality, SaMnet is an initiative to boost the quality of teaching by improving the scholarly rigour, peer support, and organisational rewards for experimentation and dissemination.

Continuing in the context of networks, **Varella** describes the European Chemistry Thematic Network Association - a forum for chemical sciences in the European higher education area. She describes the network under the headings: 1. Profile, affiliation and aims; 2. Quality assurance policy (the Eurobachelor quality label, the Euromaster quality label and the Doctorate Eurolabel); 3. Virtual educational structures (Repository of learning objects, and the EChem test); 4. Intense learning structures (Intensive schools on chemical sciences and on key competencies); 5. Profit-raising activities: Endeavours enhancing the attractiveness of chemistry.

More and more countries are paying attention to the relationship between curriculum standards and student learning outcomes on international assessments. **Chiu** claims that in today's global society, no country can afford for its citizens to be educationally marginalized. She explains the need for globalization of chemistry education specifically and outlines what can be done to promote globalization in a manner that motivates students and links international students together.

Overton from the University of Hull describes the UK experience of a discipline network for chemistry called the Learning and Teaching Support Network (LTSN). She describes the structure of LTSN, including 24 subject centres, its aims and its modes of operation, as well as its relationship with a newly established Association for Learning and Teaching.

Xu, **Southam** and **Lewis** were involved in an international (USA and Australia) research collaboration to compare student attitudes toward chemistry. An inventory called ASCIv2 validated in USA is used to measure along the two major subscales of students perceptions of (i) how difficult is chemistry? and (ii) how comfortable is chemistry? The inventory was applied to students at Curtin University in large first-year chemistry classes taught in the POGIL (Process Oriented Guided Enquiry Learning) approach, in which didactic lectures were replaced by small-group tasks, clicker questions, and online mini-lectures. First, it was demonstrated that the inventory provided valid and reliable evidence in the local setting. Comparison of student attitudes of the samples in the two countries showed significant differences.

Tan, **Mocerino**, **Treagust** and **Chandrasegaran** used two-tier multiple choice questions to investigate the understandings of Grade 10 students and pre-service teachers about stoichiometry and acid reaction kinetics. The findings identified that members of both groups had conceptions different from those accepted by the chemistry community in relation to how the properties of various acids affect their rates of reaction, as well as with respect to the species present in mixtures on completion of reaction. The difficulties are attributed to inadequate visualization at the sub-microscopic level of the properties and reactions of acids, and the authors call for more focus on these during chemistry lessons. The study also highlights the need to support pre-service teachers to identify tenacious alternative conceptions.

Guest Editorial

A personal reflection on the formation of the Chemistry Discipline Network

Welcome to this special issue of the Australian Journal of Education in Chemistry. I am delighted to be able to introduce this issue, on the topic of *Exploring the Benefits of Networks in Tertiary Chemistry*, which includes papers by leaders in chemistry networks from around the world. As the inaugural Director of the Australian Chemistry Discipline Network, I have personally benefited from this relatively new network since it was formed in 2011. It is interesting to see how these larger networks have been sustained and grown over longer periods. We hope to benefit from their experiences and learn from their challenges.

The Chemistry Discipline Network came into being in mid-2011, as one of the final funding opportunities before the Australian Learning and Teaching Council (ALTC) closed. I was interested in the opportunity to be involved in a discipline learning and teaching network in chemistry, but when I contacted colleagues to ask whether they were preparing an application, it was suggested that I write one myself. I had no previous interaction with the ALTC. Fortunately, my experienced colleagues were helpful with drafting the EOI, and so the Chemistry Discipline Network was born. As co-applicants, I invited people I knew personally, including academics I had met at an ASELL workshop in Sydney. Initially, I was faced with a poor gender balance on the application, and so I specifically sought out women who have an interest in the tertiary teaching of chemistry. This process was of immediate benefit, because I met several women with whom I am now working closely.

My reasons for deliberately seeking a gender balance on the application were as follows: Although a large proportion of the unglamorous business of teaching large classes of first year students (along with the concomitant counselling and administrative tasks) is performed by female academics, we are poorly represented at the higher levels in academia. Having a teaching focus is more common for female than for male academics in chemistry, partly because it is more compatible with childcare responsibilities than a laboratory research focus. However, the big names in SoTL in Australian chemistry are predominantly male. It seems that the extra time required, on top of the full time job of teaching students and unavoidable administration, is less available to women. This is the time needed to write grant applications, publish Scholarship of Teaching and Learning (SoTL) papers and travel to conferences and meet others with similar interests. For example, neither ASELL nor ALIUS, which are both large ALTC projects involving mostly chemistry academics, have women chemists involved. This contrasts with the situation in other countries, particularly the United States, where many of the leaders in chemical education are women. Notably, most of the invited contributions to this special issue are women leading chemistry networks internationally. It appears to me that networking is at the heart of growing a research profile in SoTL, because it is through personal contacts that collaborations and grant proposals evolve. My experiences so far with the Chemistry Discipline Network confirm this; for example, I have been invited to collaborate on grant proposals by people I met through the Network. I have also attended meetings in my role as Director, where I have met leaders in SoTL in science from around Australia. For these reasons, I am making a conscious effort to ensure that women are represented and given opportunities within the Network.

I am grateful to the members of the Australian tertiary chemistry teaching community who have become involved in the Network. This type of work is not rewarded through the usual university channels, and can be very time consuming. For me, the rewards are the sense of connection with others, learning from their experiences and hopefully improving my teaching. It is also refreshing to connect with people of similar teaching philosophies who face similar challenges.

I hope that you find this special issue of the Australian Journal of Education in Chemistry with the theme *Exploring the Benefits of Networks in Tertiary Chemistry* to be interesting. I am honoured that important international network leaders have contributed articles and I commend them to you.

Guest Editor

Dr Madeleine Schultz
Chemistry, Queensland University of Technology
madeleine.schultz@qut.edu.au

The Chemistry Discipline Network: One Year On

James Mitchell Crow[1], Glennys O'Brien[2] and Madeleine Schultz[1]

[1]*School of Chemistry, Physics and Mechanical Engineering, Queensland University of Technology, Brisbane QLD 4000* [2]*School of Chemistry, University of Wollongong, Wollongong, NSW 2522, madeleine.schultz@qut.edu.au, gobrien@uow.edu.au*

Abstract

The Chemistry Discipline Network was funded in mid-2011, with the aim of improving communication between chemistry academics in Australia. In our first year of operation, we have grown to over 100 members, established a web presence, and produced substantial mapping reports on chemistry teaching in Australia. We are now working on the definition of standards for a chemistry degree based on the Threshold Learning Outcomes published by the Learning and Teaching Academic Standards Project.

1.0 Introduction

The formation of the Chemistry Discipline Network in July 2011 was timely, given that it occurred shortly after the publication of the Science Threshold Learning Outcomes (TLOs) by the ALTC Learning and Teaching Academic Standards project.[1] In parallel with this process, chemistry-specific TLOs were also drafted in early 2011, articulated as high-level statements that would need to be “unpacked” in order to be implemented. Expanding the chemistry TLOs into standards suitable for use by the newly created Standards Panel, which will support the Tertiary Education Quality and Standards Agency’s auditing process, was one of the key tasks assigned to the Chemistry Discipline Network.

1.1 Network building

Formation of the Chemistry Discipline Network was first announced at the Australian Council of Deans of Science (ACDS)[2] Teaching and Learning (T&L) conference in July 2011. At the same time as the Chemistry Discipline Network was funded, several other science discipline networks were also awarded, in biology, biomedical science and mathematics. These networks were to be supported by the overarching Science and Mathematics Network (SaMnet), which was funded at around the same time. It was expected that the different disciplines would work together and cooperate. Prof. John Rice, from the ACDS, was asked by the ALTC to become involved to encourage cooperation between the science networks.

The Chemistry Discipline Network’s first meeting was arranged to coincide with the Australian Conference on Science and Mathematics Education (ACSME), in Melbourne in September 2011. The meeting formed part of a “Discipline Day” at which each of the newly created discipline networks would meet. This event took place not long after the grant was announced. Prior to the meeting, every chemistry academic at the five different universities in Melbourne was invited. Despite the short notice, the meeting was very successful, with over 30 chemistry academics from 20 (of a total 39 where chemistry is taught) different Australian institutions attending. We discussed the role of the Network and also how we should encourage participation. The 30 attendees formed the initial pool of members.

During the same conference, we held a "nuts and bolts" session around how to encourage engagement with the planned network website (http://chemnet.edu.au). This process generated many excellent suggestions. The general view seemed to be that the website would be the key part of the network.

From this first meeting, the initial goals of the network were established: to map the current undergraduate teaching, nationally, in terms of delivery methods, content and assessment; to map current teaching against the Chemistry TLOs; and to form a library for learning objects shared among members. Web-based discussion fora were also desired, as a route to engagement between network members. Later goals were more ambitious - to work towards agreed common standards and even shared assessment items for benchmarking between universities.

1.2 Network growth

In its first year, the Chemistry Discipline Network has grown to over 100 members, reflecting ongoing efforts to publicise the Network’s activities. In February 2012, for example, we were featured in a full page article in Chemistry in Australia, the news magazine of the RACI. This resulted in new members joining the Network, as well as generating discussion at universities that already had members. As our membership has gradually increased, there has been a steady stream of email traffic and discussion of Network activities among the chemistry academic community, between the Directors and individuals around Australia, and also through the project officer. We hold monthly Skype meetings at which general business is discussed and members have the opportunity to bring up any issues. These regular meetings keep things moving forwards for the network. Every Australian university has at least one staff member in our Network; the total membership currently stands at 108 university chemistry academics.

The Network’s website was launched in December 2011, and we now have over 50 registered users. Interestingly, despite the desire for a website expressed during our initial meeting, the website has not turned

[1] http://www.olt.gov.au/resource-learning-and-teaching-academic-standards-science-2011

[2] http://www.acds.edu.au– ACDS has 40 member institutions across Australia

out to be the central hub of the network. During 2012, functionality has been added to the website, including discussion fora, a calendar with upcoming events of the Network as well as conferences of interest, and a resource-sharing form. However, the use of the website has been low; although many are interested in discussing teaching issues and sharing their strategies, it seems most are too busy to log in to the website and post their thoughts. In spite of this relatively low use, some interesting discussions have occurred.

We sponsored a symposium held during the RACI Chemical Education Division conference in Adelaide in July 2012 on benchmarking and standardised exams, with Prof. Tom Holmes from the American Chemical Society Examinations Institute as plenary speaker. This symposium included both tertiary and secondary educators, and experts at the secondary level were also invited. It brought together national and international researchers, and stimulated discussion on the possibilities for using some standardised assessment in Australian tertiary chemistry.

One of our goals was to improve communication between academics at smaller, regional universities who are often isolated with very small chemistry departments. Evidence of the impact of the network is that three such people, from UNE, JCU (Cairns) and SCU attended several of our meetings and discussed their teaching with others. Two of these attended the ACSME and our associated general meeting in September 2012.

We presented progress of our network at the meeting of the ACDS T&L meeting in July 2012. The Network has been recognised by both the RACI and the ACDS as the key player in establishing standards and assessment of threshold learning outcomes, and helping develop new accreditation standards.

Our second general meeting was held during the Discipline Day of ACSME in September 2012. This meeting aimed to begin the work translating the TLOs to specific standards, as discussed in detail below.

2.0 Network projects

2.1 Snapshot mapping

We have completed a snapshot mapping of all chemistry subjects (units of study) as taught at 12 universities in Australia in 2011. The report on this mapping exercise was released on our website,[3] and the link was sent to the Heads of School for all Chemistry Schools and Departments around Australia. The following data were gathered for each chemistry subject at each participating institution:

1. year level
2. subject code name
3. internal or distance
4. core or elective for chem major, or a service teaching subject
5. prerequisites for entry
6. content description
7. textbooks
8. % Organic, % Inorganic, % Physical, % Analytical, % Biochem, % Gen Chem, % non-chemistry content

Face to face activity:

1. total lecture hours
2. total tutorial/workshop/PASS hours
3. field trip
4. total prac hours
5. total contact hours
6. use of clickers

Assessments

1. prac report format
2. prac assessment %
3. assignment/workshop/tutorial %
4. mid semester exam(s) %
5. presentations (poster/oral/blog) %
6. final exam %
7. assessment group work %
8. % of all assessment that is MCQ
9. % of all assessment that is online

Other

1. approx numbers 2011

This mapping exercise showed that across the participating institutions, content of the first year subjects are similar, but several different themes with varying emphases of the chemistry sub-disciplines are offered at the third year. Differences between institutions are also apparent in contact hours, face to face activities, group work and assessment types. This snapshot provides very valuable information on the variety of degree programmes on offer. The spreadsheet can be mined for further details. Several institutions are currently undergoing curriculum renewal and so a repeat of the mapping exercise is planned for 2014.

2.2 Mapping the chemistry TLOs

We have also completed the mapping of all first year subjects in the BSc(Chem) against the Chemistry TLOs,[4] at six universities in Australia. This mapping is being undertaken to illustrate the extent to which content and activities currently delivered and assessed, address each of the TLOs. This process is currently being expanded to include second and third year subjects. This is valuable supporting material for the working group developing the assessable standards to present to the Standards Panel. The report on this exercise, which includes units that are compulsory for BSc students but not chemistry units, has also been released on our website.[5] This significant work puts the Network in a strong position to work with TEQSA to establish standards for tertiary chemistry.

Alongside the 'snapshot' report, these two documents are major achievements and the interest in them, from Heads of Disciplines, Heads of Schools and Deans, demonstrates that we are achieving important outcomes for tertiary chemistry teaching in Australia. The importance of these reports for the TLOs to standards

[3] http://www.chemnet.edu.au/sites/default/files/files/Report_Mapping_Chemistry_Australian_Universities.pdf

[4] http://www.chemnet.edu.au/sites/default/files/files/Chemistry_TLOs_realigned_Nov_2012.pdf

[5] http://www.chemnet.edu.au/sites/default/files/files/Report_TLO_Mapping_Chemistry_Australian_Universities.pdf

work cannot be understated. They also form a substantial base for the RACI as this organisation moves forward with its new accreditation processes. The incoming President of the RACI is closely involved with the TLO mapping work.

2.3 TLOs to standards

The ongoing formulation of standards for the TLOs is one of the major tasks assigned as part of the grant, and is now occupying much of our energy.

Our second general meeting, at the 2012 ACSME Discipline Day, took the form of a structured three hour workshop of group discussions as the first major step toward enunciating discipline standards for the Standards Panel. This work will also be used as part of the basis from which the RACI will redevelop its university accreditation process, which is currently under renewal.

The actual process of TLOs to standards is very much in development as we, and other disciplines, seek to formulate standards which represent TLOs and ways of demonstrating that students have met these standards. In developing standards of achievement, standardisation of chemistry degree programmes across Australian universities as identical is not intended and, given the results of the mapping snapshot, nor would that be possible. Thus, standards must be sufficiently generic so as to cover for the various themes and different emphases in chemistry degree programmes on offer in Australia.

The workshop discussions during the Discipline Day focussed on the first section of TLO 2, essentially the “body of knowledge”, and the second section of TLO 3, essentially the “recognised techniques and appropriate techniques and tools”, required of a chemistry graduate. Different groups within the workshop were tasked with examining these TLOs from two specific viewpoints: one discussion focussed on essential content and depth expected by the end of the degree, accounting for different themes in degree courses offered; and the other discussion centred around the assessment tasks students would be expected to do and how these can relate back to the two TLOs.

So what depth and breadth of chemistry would you expect as a threshold to be achieved by a student on graduation with BSc(Chem)? What competence do you expect such a student to be able to demonstrate? By what means would you gauge that the student had met these criteria? The outcomes of the group discussions were an indication of the difficulty of tackling these issues. One could conclude that little tangible progress was achieved, especially on TLO 2.1 ("Exhibit depth and breadth of chemistry knowledge by demonstrating a knowledge of, and applying the principles and concepts of chemistry.") Group members concluded that they felt qualified to prescribe minimum graduate knowledge only within their own sub-discipline. However, in going through this process, one possible pathway forward was identified – that subsequent discussions include sub-discipline groups to delineate the threshold-level body of knowledge required within each classical sub-discipline of chemistry: organic, inorganic, physical, analytical. Discussions regarding practical skills were somewhat more fruitful and some progress was made in deciding what could be considered essential laboratory / technique / instrumentation knowledge and skills for a chemistry graduate.

With respect to demonstrating student achievement of formulated standards it is important to note that we do not need more assessment, we need some assessment redesigned. Some of the assessments we currently use will be required to demonstrate students have achieved the threshold criteria, that is, assessment must be fit for purpose. Such assessment is not about scraping 50% and a Pass grade, where the specifically known content is not distinguished from what the student has failed to grasp. Further, assessment of standards covering the more generic TLOs will need attention, such assessment was notably thin in the results of the snapshot mapping project.

As the first discussion along this path the collected commentary is invaluable. The next series of discussions is being planned over the next four months in light of these experiences, and also in view of the activities of other discipline groups going along the same path. These discussions will, of course, need to address the other more generic TLOs as well. Input from others is welcome and will be sought via the Network, the RACI and Heads of Schools.

3.0 Conclusion

TLOs and related outcomes aside, the most important role of our Network is simply to facilitate the natural interactions that occur when people speak to one another within their teaching roles, and chemistry academics Australia-wide are meeting through the Network. For example, during meetings, members have shared some of their frustrations and strategies in dealing with poorly prepared undergraduates. Others have shared a variety of teaching materials including practical laboratory experiments, in-class activities and clicker questions, and discussed their strengths and weaknesses. We now know who will be attending national and international conferences, and can plan to meet in person to discuss collaborations, grant applications and general chemistry teaching issues. These less tangible outcomes result from connecting people with shared interests, who would not otherwise know each other. Enhanced communication within the community of chemistry academics in Australia is already leading to more collaboration on grants, and the more experienced members are sharing their knowledge of publishing in the Scholarship of Teaching and Learning (SoTL). For academics who are new to SoTL and for those who have already been working in the field, the network has proved to be a way to generate fruitful discussions and to get to know people, virtually and in person.

Learning to Lead Change: SaMnet's action-learning projects

Will Rifkin,[1] Manjula Sharma,[1] Andrea Crampton,[2] Brian Yates,[3] Kelly Matthews,[4] Stephanie Beames,[5] Cristina Varsavsky,[6] Elizabeth Johnson,[7] Susan Jones,[8] Marjan Zadnik[9] and Simon Pyke[10]

[1] School of Physics, University of Sydney, NSW 2006, AUSTRALIA, [2] School of Biomedical Sciences, Charles Sturt University, Wagga Wagga, NSW 2678, AUSTRALIA, [3] School of Chemistry, University of Tasmania, Private Bag 75, Hobart, Tasmania, 7001, AUSTRALIA, [4] Teaching and Educational Development Institute, University of Queensland, St Lucia QLD 4072, AUSTRALIA, [5] Faculty of Science, University of Technology Sydney, PO Box 123, Broadway NSW 2007, AUSTRALIA, [6] School of Mathematical Sciences, Monash University, VIC 3800, AUSTRALIA, [7]. Faculty of Science, Technology and Engineering, La Trobe University, Melbourne VIC 3086, AUSTRALIA, [8] School of Zoology, Private Bag 5, Hobart, Tasmania 7001, AUSTRALIA, [9] Department of Imaging and Applied Physics, Curtin University, GPO Box U1987 Perth, Western Australia 6845, AUSTRALIA, [10] School of Chemistry & Physics, The University of Adelaide, SA 5005, AUSTRALIA, SaMnetAustralia@gmail.com

Abstract

Eight project teams at universities across Australia are attempting to change how chemistry is taught as part of a larger effort to improve the teaching of science and mathematics, generally. The teams are involved in what are called action-learning projects, "acting" to change the teaching in their school or faculty while "learning" to lead change. We outline here why this initiative is being pursued, describe the projects in chemistry, and explain the nature of support provided by the Science and Mathematics Network of Australian University Educators (SaMnet). We then enumerate the key principles involved in this effort to transform a range of individual initiatives to improve teaching into a sector-wide movement for change.

Introduction

Eight action-learning projects are under way in the discipline of chemistry supported by the Science and Mathematics network Australian of university science educators (SaMnet). They range from improving laboratory practices in biochemistry to implementing student-response systems in first-year lectures in a service subject. Some projects are developing new teaching approaches, while others are adapting what has worked in one context to a new setting. More than a dozen other action-learning projects are being pursued across disciplines in science and mathematics. Some projects will have implications for university chemistry teaching, such as intensive mode delivery of a semester-long subject.

These activities are more than just clever experiments in how to improve one's teaching. They are labelled "action-learning" projects in that members of each project team are meant to be developing the capability to influence the teaching of colleagues, both locally and at other institutions. They are to evaluate not only the potential advantages of what they are doing but how it fits with traditional modes of operating, embedded values of colleagues, and key performance of indicators of their heads of school, deans, and administrators up the line. These projects are meant to move beyond "the usual suspects," the 10-15 percent of academic staff who could be classified as "innovators" or "early adopters" (Rogers, 2003). These "usual suspects" tend to populate education special interest groups and attend teaching-oriented workshops or conferences. Such dissemination needs to occur beyond the bounds of the discipline of origin, as well. Fairweather's (2008) review of the literature found that, while many worthwhile teaching approaches that were developed in one discipline could be readily adapted to other disciplinary contexts, there was little of this cross-discipline uptake.

Improvements in university science teaching have been supported through approximately forty projects funded by the Australian Learning and Teaching Council and its predecessors (e.g., Carrick, 2007). Despite such developments as inquiry-based laboratory exercises, science teaching retains a reputation for being content-heavy and didactic with assessment based predominantly on exams. Efforts to share newly developed or adapted approaches usually fail to continue when a project's funding ceases (D-Cubed Newsletter, 2011) or when the innovative teachers move on.

The ability for one academic to influence how others teach can be understood to represent a form of "transformational leadership", which Southwell and Morgan (2009) identified in a review of the leadership literature that they saw as relevant to higher education in Australia. Southwell and Morgan (2009) explain, "Transformational leadership engages the needs, aims and abilities of individual followers so that they are drawn up into the vision and goals of the organisation and effect significant improvements through common interests and cooperative actions" (p. 29). That relevant "organisation" in our case is embodied in the national network, SaMnet, which in turn intends to represent the enterprise of university teaching in science and mathematics in Australia beyond the time of its current seed funding.

In taking this angle, the SaMnet effort follows in the footsteps of the project: *Active Learning in University Science (ALIUS) – Leading Change in Australian Science Teaching*, pursued by chemistry and physics academics Bedgood, Bridgeman, Buntine, Gardiner, Lim, Mocerino, Morris, Pyke, Southam, Yates, and Zadnik (2012). That project's final report underlines the value that project team members gave to leadership development workshops and to insight provided into their roles as "early adopters" in the diffusion of good teaching practices (Bedgood *et al*, 2012: p.6). They also articulated greater awareness for their own setting of key concepts in spurring organisation, such as instilling in colleagues a "sense of urgency" to change how they teach and developing a "guiding coalition" in their school or department (*Ibid*., p.6). To support ongoing change, they conclude that, "Three domains have been identified as the architecture upon which sustainable L&T innovation will be built. These domains include Learning and Teaching innovation in project leaders' and colleagues' classrooms, development of project leaders as *Science Learning Leaders*, and creation of a Science Learning Hub to serve as a locus and catalyst for the development of a science teaching community of practice" (Bedgood *et al*, 2012: p.5).

SaMnet is also following cues from the "leadership academies" formed in science in the US via Project Kaleidoscope (2011) as well as from the cross-disciplinary Change Academy run by the UK Higher Education Academy (2011).

Capacity for transformational leadership can impact not only on colleagues but on those in higher positions, the heads of school, deans, etc., referred to above. The use of influence individually can be augmented by use of influence collectively, which is a form of "distributed leadership" (Gossling, Bolden, and Petrov, 2009; Spillane, 2004; Harris, 2004). Distributed leadership represents influence that is not based solely on rank or control of valued resources. Rather, it draws on the abilities of individuals and groups to articulate a vision, create a sense of urgency, and provide support for others who can be persuaded to change.

Leadership distributed across individuals in multiple disciplines would enable academic science in Australia to "speak with one voice" about educational issues of concern (Sharma, Rifkin, Beames, Johnson, Varsavsky, Jones, Yates, Zadnik, Crampton, Matthews, and Pyke, 2012). These issues would include establishment of teaching and learning standards to be enforced by the Tertiary Education Quality Standards Agency (TEQSA). There is also the Commonwealth government's lifting of caps on university enrolment and their agenda to raise enrolments at universities from 35-percent to 40-percent of the eligible age cohort. This initiative, coming to be known as the "inclusion" agenda, is drawing students from backgrounds that are under-represented, such as from families or communities with low socioeconomic status and those who are the first-in-family to attend a university.

Within this context, one can see that an action-learning project on implementing a student-response system in a large, first-year lecture in chemistry has implications well beyond the learning of the individual students in that one class. In this article, we will elaborate on this trail of causality from individual initiative to potential changes in the teaching of science across Australia, which is the strategy being pursued by SaMnet. First, there will be a brief listing of the eight action-learning projects in chemistry that are currently under way. This listing is meant to alert readers to projects that may be of interest and to identify examples from the "SaMnet movement" that should be visible at upcoming conferences. Second, we will outline what is involved in pursuit of these projects to suggest what to expect from the project team – from their proposed plan of action to their case study on how to implement change. Third, we will elaborate on the aspects of the SaMnet initiative that are oriented toward collective action and will introduce concepts and literature from the social sciences to rationalise this approach. We will conclude by (1) tying these threads together to underline how individual action toward creating mass change can be seen as part of an academic's "day job" and (2) suggesting how such efforts align with traditional reward structures of science – publication and leadership in the discipline.

2. Who is involved, doing what – 8 chemistry projects

The SaMnet initiative is currently supporting eight action-learning projects in chemistry. The projects are based at seven universities, which include regional universities and urban ones, teaching-intensive and research-intensive universities. Most of these eight projects focus on chemistry alone while a few address chemistry in concert with a second discipline. Some other SaMnet projects address chemistry as part of a focus that crosses undergraduate science programs, generally, but they are not listed below (though they can be viewed on the SaMnet website – http://www.samnet.edu.au).

- Williamson, Metha, Willison, and Pyke of the University of Adelaide are aiming to change the way content is delivered in Foundations of Chemistry lectures. They will implement a shift from a traditional format to a Process Oriented Guided Inquiry Learning (POGIL©, http://www.pogil.org/)-style approach in order to provide students with more opportunities to engage actively with course material. They plan to cater to – and engage – increasing numbers of students who have no chemistry background.
- Brown, Southam, Sneesby, and Zadnik of Curtin University are employing a constructive alignment process (Biggs and Tang, 2007) to map subjects. They are developing diagnostic measures and assessment tasks to engage and motivate students as well as to assess their competence in core laboratory skills.
- Schultz, Tasker, Beames, and Savage of the Queensland University of Technology (QUT) are aiming to improve lecture delivery in first-year chemistry by enabling instant feedback to polls and open-ended questions. They are employing Student Response Systems (SRS), which have been shown to improve student engagement and performance, while, they argue, helping academics avoid burnout.

- Thompson, Rayner, Hughes, and Varsavsky of Monash University are redesigning laboratory exercises to offer a more open selection of tasks and to incorporate experimental design challenges, group work, opportunities for multimedia presentations and peer assessment. They are adapting approaches that the literature and experience indicate are successful. They are starting in single a large first-year subject, with similar strategies then being rolled out in second and third year for chemistry, physics, and biology.
- Huth, Potter, Yench, and Johnson of La Trobe University are developing an efficient laboratory program that mixes "traditional" laboratory activities, which they characterise as verification, with enquiry-based activities. These new activities are to be supported by tutorials/workshops and online materials and to link up to and complement the lecture program. They aim to enable students to systematically develop relevant skills and capabilities (including communication and higher-order thinking skills) and to inspire them to continue with chemistry in their studies and career.
- Hudson, Neto, Symone, Gysbers, Schmid, Bartimote-Aufflick, and Bridgeman of the University of Sydney are creating strategies for engaging students in active learning. Their focus is on visualization of chemical phenomena for large lectures. They are looking to use "clickers" (student response systems), buzz sessions, and peer instruction related to students' understandings of lecture demonstrations.
- Stewart, Kant, Baldock, Denyer, and Bridgeman of the University of Sydney are investigating whether undergraduate physics and biochemistry labs are achieving desired learning outcomes by using the tested framework, Advancing Science by Enhancing Learning in the Laboratory (ASELL; http://www.asell.org/). The aim is to identify what problems exist, why they exist, and how to change the laboratory exercises to improve outcomes. They will focus on several experiments in first-year physics and second-year biochemistry, and they will implement changes based on the results of the ASELL analysis.
- Fildes, Bedford, O'Brien, Keevers, and Carr of the University of Wollongong are aiming to increase student engagement by moving some student activity away from the currently passive, lecture situation to a more active environment. They will restructure teaching approaches as workshop activities based on the framework, Process Oriented Guided Inquiry Learning (POGIL©).

What one can see above are specific initiatives of the sort that would be on the "wish list" of many who seek to improve or rejuvenate their chemistry program. SaMnet seeks to provide a structure and external support for pursuing these initiatives.

3. Elements & process of a SaMnet project

3.1 Proposal

The projects listed above came about, and are being supported, through a multi-step process. SaMnet elicited proposals throughout the latter half of 2011 by presentations and e-mails relayed via associate deans of education/teaching and learning in science, deans of science, discipline-based groups, communities of interest formed around previous projects funded by the Australian Learning and Teaching Council (ALTC), and delegates of the Australian Conference on Science and Mathematics Education (http://sydney.edu.au/iisme/conference/2011/index.shtml).

Proposals followed a format previously developed for internal projects at Curtin University and the University of Queensland while requiring some of the information needed for a nationally competitive grant (e.g., to the ALTC). Notably, applicants were required to assemble a team of individuals with complementary skills and abilities. SaMnet specified a need to include: (1) a junior or innovative academic, someone who sees a change that is needed; (2) a senior academic who recognises the challenges faced in creating change; (3) an academic developer to provide insight from the educational literature as well as across faculties to recognise university-wide initiatives and performance indicators; and (4) the associate dean for education/teaching and learning in science in the faculty in order to assure that the project aligns with faculty-wide requirements and the key performance indicators (KPIs) of heads of school and the dean.

Proposals had to identify the scope being addressed in the project, such as what degree programs, how many students, and how many colleagues would be affected. The aims and rationale had to be articulated, of course, as well as precedents known through experience and in the educational literature. A knowledge of precedents was required in order to avoid having people reinvent the wheel, or the flat tyre, as the case may be, and to bolster the tradition of consulting the scholarship of teaching and learning (SoTL) literature as a first resort.

The proposal needed to define desired outcomes and how they would be measured. It also had to articulate why those outcomes would eventuate from the strategies being employed. There was a section of the proposal form to be completed on dissemination, with instruction that publication should be an aim so that project participants were not only providing leadership within their faculty but also intellectual leadership more broadly. The proposal included a section on capabilities that applicants felt that they needed to gain to make their project successful and types of information that they could use from others. On the latter, they were asked which of the communities of practice that SaMnet is consolidating would be the most relevant, the one on educational standards, the one on laboratories and inquiry learning, or the one on new educational technologies. Applicants needed to draft a timeline for their project. They were to identify which aspects of their project they were least sure about, and where they could use help, whether in co-opting another team member or in devising an evaluation scheme, for example.

There was no section of the proposal on a budget because SaMnet does not provide direct financial support. Some projects were already funded internally, and others would potentially employ the imprimatur of SaMnet to leverage internal support. Still others were being pursued as part of the normal duties of the applicant team or the desired direction for their school or faculty. The orientation was toward what the noted organisational theorist, Karl Weick, calls "small wins" (1984), positive though incremental and repeated progress toward desired goals. This strategy aligns with research findings of Tobias (1992) and Gibbs (2006), both of whom recognise that significant improvements in teaching can be traced to cultural change within a department, a unit that can support and reward modest initiatives.

So, the proposals followed the format of many research proposals, albeit in abbreviated form (4-6 pages in a *pro forma*). However, there was perhaps more attention to human and organisational capabilities and challenges. These latter areas would align with the action-learning aspect of the projects, in that the projects are meant to serve as practice and to build capabilities.

Proposals were due for submission in early December 2011. They were vetted in December 2011 and January 2012, and formal feedback was provided by at least two expert reviewers by March of 2012. Formal acceptance letters were sent to team members and their dean of science. Project participants were invited to day-long workshops scheduled to accommodate their teaching commitments, *i.e.*, in February before session began and in April during the Easter break.

3.2 Critical friend

Each SaMnet project has been "adopted" by a critical friend from SaMnet's steering committee. The role of critical friend has been described as a kind of mentor who offers compelling questions and provides guidance with a light hand (see, for example, Miller, Vandome, and McBrewster, 2011; Conole, Brown, Papaefthimiou, Alberts, and Howell, 2010; and Costa and Kallick, 1993). In the case of SaMnet, the critical friend is to contact each team every four to eight weeks to find out what is occurring and to hear about challenges, successes, and failures. They are to offer advice but not prescriptions and ask questions and point to factors that project team members may not have considered. They are also to clarify what SaMnet hopes the project will deliver, such as workshop attendance or a conference paper.

If a project does not seem to be progressing, they are to ask questions that can reveal why and to remind participants that the project is about developing team members' capabilities. One such capability is the ability to focus on an effort that may be a little outside one's normal scope of duties and potentially outside one's immediate comfort zone. Critical friends are to use any roadblock as a potential "teachable/learnable moment."

Critical friends record a few bullet points from their conversations with team members onto the SaMnet website in a "members only" area. These points are not meant to publicise success or failure in order to compel compliance. Rather, they are to let teams clustered by region (e.g., Queensland and the Northern Territory) know how each other are going, to highlight what may be common challenges, and to share useful strategies for engaging with colleagues and for being persuasive.

In summary, the critical friend role involves being supportive but not directive. They are to ask hard questions but in a developmental way.

3.3 Workshops

Each workshop has focused on building capability in both intellectual leadership and organisational leadership. It also provided time for project teams to develop their plans and specify next steps, as it was realised that team members can have difficulty in drawing themselves away from ongoing duties to pursue a voluntary, additional project, particularly a project that required alignment of timetables across people with four disparate areas of responsibility.

For each workshop, the focus in the morning has been on getting project team members to talk with one another about their projects both within teams and across teams. The notion is that participants would initially be more interested in the practical aspects of their project and less interested in the conceptual aspects of leading change. University-based, leadership workshops have all too often been reported to be a stream of PowerPoint slides and management jargon that is unrelated to academic science and its teaching. We sought to avoid that.

A key element in each workshop has been a focus on the scholarship of teaching and learning. A range of research methodologies have been outlined and discussed, from more structured, survey-based approaches to more emergent, ethnographic approaches. SoTL in science was characterised as tending toward the more controlled, quantitative approaches that typify the rest of science but with increasing acceptance of more qualitative approaches that lend an air of authenticity, that capture the experiences of students and/or staff. Team members discussed how to approach their project's SoTL effort by selecting approaches representing a combination of the research strategies discussed. Teams were also walked through the sequence of steps in SoTL research, from selecting a research question and object of study through ethics clearance, data gathering and analysis, and on to synthesis and publication.

In the afternoon, attention shifted from project specifics and educational research toward organisational leadership. Senior academic administrators, such former pro vice-chancellors, have been invited to serve as "patrons" to discuss how they learned to lead change. These accounts of experiences of leadership were conceived as a gradual introduction to concepts of leading change. It was suspected that this topic would not be seen as particularly relevant to science and mathematics academics unless it was couched in familiar examples and experiences of respected academics.

The workshop segment on leadership concepts has begun with participants discussing their experiences of change and factors that they felt helped to make such an experience a positive one for them.

They were asked analyse a particular management conceptualisation of leading change – Kotter's 8 steps for change (1995) and Rogers's factors that indicate whether something new will be adopted quickly or slowly (2003). Both these frameworks were well received in the ALIUS project. Also introduced were notions of transitions, the emotional stages involved in taking on new approach and giving up something old, which is attributed to Bridges (1991), and distinctions between organisational challenges and emotional challenges described by Wilber (2001). These latter two frameworks were recommended by professional staff development officers, the university staff who are responsible for enabling heads of research units and deans to lead more effectively. Participants were asked to identify which elements in a change strategy would be easy to implement and which elements hard. The aim here was to have participants evaluate the relevance, usefulness, and difficulty in using these frameworks on their own projects, rather than asking them to accept their value without scrutiny.

Workshop participants were asked to explain the relevance of the framework for implementing change that they had discussed to (1) their own experiences, (2) the experiences and insights related by the "patron", and (3) their project. Team members then each had to identify a key stakeholder in their project initiative (e.g., students or tutors or the head of school) and determine the pros and cons of their SaMnet project from the perspective of each one. This discussion emphasised that strategic leadership of change involves seeing worthy initiatives from the perspectives of others. In other words, one needs to frame or re-frame one's aims in terms of what others value.

That was a key take-home message, the idea that one needs to be strategic about how to approach each stakeholder in a subject, laboratory, or other aspect of teaching. Furthermore, being strategic means acknowledging others' views and values and responding to them. The leadership concepts introduced provide frameworks for doing that analysis and strategising. They are also meant to assist in selecting what sort of approach to take in what phase of a project.

3.4 Reporting & Publishing

Project teams are to provide an account of their experiences and progress to their respective critical friends every month or two. They are to summarise these matters on a more frequent basis on the project website or in some other common record-keeping document (such as a shared Google Doc). They are expected to discuss their progress at two SaMnet workshops each year as well as at opportunistic meetings, such as at conferences where it is evident that members of several project teams are attending, such as the national Chemistry Education conference in Adelaide in June 2012.

Teams are meant to produce refereed publications in order to earn credit for their efforts in a mode that research scientists recognise, *i.e.*, journal articles. For some, SoTL publication is a new venture even if "scholarly teaching" is not new to them. Each team should include someone who has published in SoTL before, but there is also support available from the critical friend as well as from members of other project teams who share an interest in their project.

Two forms of publication are meant to emerge. One is on the educational innovation and its impact on students. That could detail improvement in students' understanding that corresponds with implementation of inquiry learning strategies in a first-year subject. Another article would be a case study of strategies employed and impacts identified when trying to get colleagues to adopt a similar approach in their teaching. For example, in what ways does successful implementation of inquiry learning in a first-year subject lead to more ready uptake in a second-year unit? What strategies aside from reporting of convincing results need to be in place to foster adoption?

Aligned with this latter effort, SaMnet steering committee member Kelly Matthews of the University of Queensland has developed a set of reflective survey questions. The questions are based on a framework offered by Timperley and Parr (2005) that ties successful change to factors of beliefs and values, knowledge and skills, and outcomes.

In summary, the reporting and publishing elements of SaMnet projects are oriented toward enabling teams to get help, to see how other teams are going, to earn credit for their efforts, and to reflect on how they could become more influential. The publication in SoTL and the one on driving change represent the two prongs of leadership that are being developed, respectively – (1) intellectual leadership and (2) organisational leadership.

Through these action-learning projects, SaMnet is attempting to provide structure, a national imprimatur, training, and support for making local initiatives to improve science teaching more successful. It is also providing a national network through which some of this support and insight can be delivered peer to peer both within disciplines, such as chemistry, as well as across disciplines.

4. Concepts behind this approach

In order to provide leadership development for both the current and the next generation of science academics who want to focus on improving teaching, the project teams are mixed, including both senior and junior academics. The individuals involved form a network for both support and dissemination, as just noted. However, the aim is to have the network evolve into a movement, an organised push in a particular direction that can engage more than just the 400 keenest of the estimated 4,000 full-time science academics in Australia.

This notion of a movement has been articulated by Parker Palmer (1992), a respected US-based sociologist of higher education. He describes a movement as a bottom-up approach, like the "free-speech movement" in the 1960s or the women's movement initiated soon thereafter. Parker explains that inventions of isolated individuals need to become the work of groups that provide mutual support. We see that in Australian science in the growth of education special interest groups within disciplines. This stage should be followed, Palmer explains, by widespread public discussion of issues and opportunities. Such conversations have been fuelled in recent years by increases in the volume of the scholarship of teaching and learning and attention to establishing teaching and learning standards to be enforced by the TEQSA. Another log on the fire has been the Commonwealth government's lifting of caps on university enrolment, mentioned earlier. One can conclude that Palmer's "widespread public discussion" is growing in Australia.

Parker argues that an additional stage is crucial, the establishment of reward structures to sustain a movement for change. In science, that currently means enabling academics who teach well to achieve by standards employed to assess the research of their colleagues, *i.e.*, refereed publications and exercise of leadership in the field. SaMnet is aiming to provide avenues for achievement and acknowledgement in these areas. In so doing, SaMnet is working across science disciplines attempting to do what the respected sociologists Snow and Lessor (2010) represent as aligning frames of reference of various interest groups so that a movement coalesces.

Also addressing collective action is the work of Michael Fullan, a Canadian specialist in the leadership of change in educational systems whose work has guided projects for change in Australian school systems. Fullan calls for an alignment among the efforts of individuals and organisations (Fullan, Cuttress, and Kilcher, 2005) as well as fostering of "system thinkers in action" (Fullan, 2005). These prescriptions can be understood to support (1) a coherent effort across academic staff in science, (2) regulation and incentive structures from government that reflect effective classroom practice, and (3) complementary support by university administration, *e.g.*, deputy vice-chancellors, deans, and heads of schools. This alignment would mean that an individual academic's initiative should satisfy key performance indicators (KPIs) for their head of school and dean, which are in turn designed to satisfy the government mandates to which Deputy Vice-Chancellors and Vice-Chancellors need to respond. Achieving this sort of productive alignment among academics, administrators, and government suggests a need for academic staff in science to "speak with one voice", as we noted earlier, as science academics need to represent classroom needs effectively to government. They also need to frame their efforts to satisfy KPIs of those higher in the hierarchy at their own universities, a strategy that we framed above.

This alignment is being pursued through the range of activities being undertaken by members of the teams undertaking SaMnet's action-learning projects. In addition, members of the steering committee for SaMnet are participating in, or liaising with, leaders of discipline-based networks funded by the ALTC. They have also presented at educational conferences organised by the Australian Council of Deans of Science (ACDS) and have presented to the annual general meeting of the ACDS. Responses to date from deans of science have been encouraging.

5. Conclusion

We are hoping that SaMnet supports a growing buzz of activity toward improving teaching in chemistry and across science and mathematics in lectures, tutorials, and laboratory settings. SaMnet is intended to build on growing interest and capability in SoTL and increasing accountability to government for quality of teaching in universities. At the same time, we are trying to turn the current generation of informal leaders, such as former and current ALTC grant holders, into mentors for the next generation, junior staff in the growing number of teaching-intensive appointments for example.

By collecting these players into action-learning teams, we are aiming to have more than just a network of comforting and informative conversations. We are providing structure and frameworks to foster rigour in the pursuit of worthwhile changes in teaching and curriculum in science and mathematics. Toward this end, we have outlined above how we are drawing on experience of senior level academics (*e.g.*, former PV-Cs) as well as on experience captured in the literature on leadership of change in organisations.

SaMnet is aiming to create leadership that is distributed in the sense that numerous academics in different roles are pulling in a similar direction. This leadership is meant to be transformational in nature in that it is intended to alter the culture of teaching in science. Such an impact requires what Parker called a "movement", a bottom up effort, but it also necessitates alignment up and down university hierarchy, as Fullan argues, as well as across disciplines.

In this sense, it is hoped that chemistry academics will recognise a greater context when listening to a presentation on a SaMnet project on POGIL-style lectures in second-year chemistry or an ASELL analysis of biochemistry lab sessions. That project should be seen as more than just the experiment of a single academic or a small group of colleagues. It is part of a greater initiative to boost the quality of teaching by improving the scholarly rigour, peer support, and organisational rewards for experimentation and dissemination.

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European Chemistry Thematic Network Association: A Forum for Chemical Sciences in the European Higher Education Area

Evangelia A. Varella

Department of Chemistry, Aristotle University of Thessaloniki, 54124, Thessaloniki, Greece, varella@chem.auth.gr

Abstract

The European Chemistry Thematic Network Association is a non-profit making body, focused on enhancing the quality and harmonising the features of chemical education and training all over the European Higher Education Area. Academic institutions, national chemical societies, and stakeholders comprise the over 130 members coming from thirty European countries, and with associate members worldwide.

The European Chemistry Thematic Network Association developed a series of electronic tools permitting interactive on-line access to teaching modules and tests in chemical sciences; and addressing any type of formal or adult learners. In this context, the grid-based Repository of Distributed Learning Objects is aimed at storing, identifying, localising and reusing educational information in chemical sciences. EChemTest® is an electronic test aimed at evaluating knowledge and competences in chemistry. Question banks are available at four different educational levels and a number of languages. EChemTest® examinations are offered under controlled conditions in authorised Testing Centres.

The European Chemistry Thematic Network Association implemented qualifications in the frame of the Bologna Process approach. The European Quality Labels Labels Eurobachelor®, Euromaster® and Chemistry Doctorate Eurolabel® are awarded to outcome-based programmes on chemistry or related disciplines, as well as to studies at the interface of chemistry and other subjects; and are particularly important for assuring the quality of trans-national consortia of universities. The European Chemistry Thematic Network Association operates a series of international Intensive Schools on chemistry applied in cultural heritage preservation, and a second series dealing with key competences. e-Learning possibilities for self-paced pre- and post-School use are available to candidates, who are further following structured Language for Specific Purposes courses. The European Chemistry Thematic Network Association undertook the task of enhancing the attractiveness of the discipline. In fact, both the public and early ages are approached in a multifaceted way, encompassing a website; as well as a series of competitions, inducing students to a more active involvement in chemically oriented open initiatives, or systematically revealing interesting aspects of chemistry.

1. Introduction: Network Profile, Affiliation and Aims

The European Chemistry Thematic Network Association (ECTNA) is a non-profit making body registered in Belgium, and is the outcome of fifteen years of networking activities focused on enhancing the quality and harmonising the features of chemical education and training all over the forty seven countries constituting the *European Higher Education Area* [1]. Academic institutions, national chemical societies, and stakeholders comprise the over 130 members coming from thirty European countries, and with associate members worldwide.

The statutory aims and objectives of the European Chemistry Thematic Network Association are:

- To implement, consult or supervise programmes for the assessment of skills and knowledge in chemical sciences;
- To undertake programmes concerning education and training, especially those concerning innovative approaches;
- To operate as a consultant or assessor in programmes concerning education and training;
- To provide certification of achievement when assessments have been carried out under appropriate conditions;
- To cooperate with established professional or other associations in the furtherance of its objectives;
- To extend the reach of all aspects of education in science and engineering beyond national borders;
- To provide a European framework for degrees in chemistry and related disciplines.

In order to proceed towards realisation of these goals, the European Chemistry Thematic Network Association is operating through pertinent committees in four closely interconnected areas, namely quality assurance, distance education, intense learning, and recuperation of a positive image for chemistry.

2. Quality Assurance Policy: The European Quality Labels in Chemistry

Since 1999 European universities have been going through the *Bologna Process* [2], in which forty seven states are now involved. The goal of this ambitious initiative is setting up an open *European Higher Education Area*, in which students can choose from a wide and transparent range of courses and benefit from smooth recognition procedures.

The three priorities of the *Bologna Process* are:

- Introduction of the three-cycle system (Eurobachelor, Euromaster, Chemistry Doctorate);
- Quality assurance;
- Recognition of qualifications and periods of study.

A systematic way of describing educational programmes, and thus provide transparent and compatible degree structures, is a system attaching credits to its components. The *European Credit Transfer and Accumulation System* [3] (ECTS) is student-centred and based on the student workload required to achieve the objectives of a programme – preferably specified in terms of learning outcomes and competences to be acquired.

Credits are allocated to all educational components of a study programme, and reflect the quantity of work each one requires in relation to the total quantity of work necessary to successfully complete a year of study. The *European Credit Transfer and Accumulation System* is based on the principle that 60 credits measure the workload of a full-time student during one academic year, which amounts in European study programmes to around 1500-1800 hours.

Transparency and recognition of qualifications in higher education is further guaranteed by the *Diploma Supplement* [4], a document providing a standardised description of the nature, level, context, content and status of the studies successfully completed by the graduate.

Within the above-mentioned setting, the qualifications framework for the *European Higher Education Area* has three elements:

- Introduction of the three cycles system;
- Ranges of ECTS credits for the first two cycles;
- The *Dublin Descriptors* [5], which form the basis of the qualifications framework.

For the first two cycles, the total amounts to 300 ECTS credits. Ranges have been established as follows: first cycle 180-240 ECTS credits; second cycle 60-120 ECTS credits.

European countries are now intensely developing degrees to conform to the *Bologna Process*. The European Chemistry Thematic Network Association recommends the European Quality Labels in Chemistry [6] as easily readable and comparable models, and offers them to institutions, which propose courses designed according to this framework. The European Quality Labels Eurobachelor®, Euromaster® and Chemistry Doctorate Eurolabel® are awarded to programmes on chemistry or related disciplines, as well as to studies at the interface of chemistry and other subjects; and are particularly important for assuring the quality of trans-national consortia of universities. They are adopted by the *European Association for Chemistry and Molecular Sciences* [7]. Evaluation procedures are monitored by a Label Committee and involve experts recruited from an appropriate Register.

The European Quality Labels are based on the *Budapest Descriptors* [8], a detailed adaptation of the *Dublin Descriptors* in the area of chemical sciences. A primary aim of the qualifications is to provide degrees, which will be automatically recognised by other institutions within the countries implicated in the *Bologna Process*, promoting thus mobility and employability prospects for new graduates.

2.1. The Eurobachelor® Quality Label

All degree programmes holding the Eurobachelor® Quality Label [9] are outcome-based. Each institution is free to decide on the length of studies within the frame of 180-240 ECTS credits; as well as on the content, nature and organisation of courses, provided that students become conversant with the main aspects of chemistry, and develop a wide range of competences. Hence, at least 150 ECTS credits should deal with chemistry, physics, biology or mathematics, a thesis or industrial placement equivalent to 15 ECTS credits must be incorporated. In addition, at least 90 ECTS credits should be allocated to compulsory modules on organic chemistry, inorganic chemistry, physical chemistry, and analytical chemistry. Further modules should be of three types – compulsory, semi-optional, and elective.

The following aspects are considered in the Eurobachelor® Label:

- Learning outcomes, including subject knowledge, as well as abilities and skills – chemistry-related cognitive abilities and skills, chemistry-related practical skills, generic and transferable competences;
- Modularisation of courses and contents;
- ECTS credit distribution;
- Student workload;
- Mobility;
- Methods of teaching and learning;
- Assessment and grading;
- Quality assurance.

Subject knowledge comprises at least the following issues: major aspects of chemical terminology, nomenclature, conventions and units; the major types of chemical reaction and the main characteristics associated with them; the principles and procedures used in chemical analysis and the characterisation of chemical compounds; the characteristics of the different states of matter and the theories used to describe them; the principles of quantum mechanics and their application to the description of the structure and properties of atoms and molecules; the principles of thermodynamics and their applications to chemistry; the kinetics of chemical change, including catalysis; the mechanistic interpretation of chemical reactions; the characteristic properties of elements and their compounds, including group relationships and trends within the Periodic Table; the structural features of chemical elements and their compounds, including stereochemistry; the properties of aliphatic, aromatic, heterocyclic and organometallic compounds; the nature and behaviour of functional groups in organic molecules; major synthetic pathways in organic chemistry, involving functional group inter conversions and carbon-carbon and carbon-heteroatom bond formation; the relation between bulk properties and the properties of individual atoms and molecules, including macromolecules (both natural and man-made), polymers and other related materials; the structure and reactivity of important classes of bio molecules and the chemistry of important biological processes.

Chemistry-related cognitive abilities and skills considered necessary are: ability to demonstrate knowledge and understanding of essential facts, concepts, principles, and theories relating to the defined subject knowledge; ability to apply such knowledge and understanding to the solution of qualitative and quantitative problems of a familiar nature; skills in the evaluation, interpretation, and synthesis of chemical information and data; ability to recognise and implement good measurement science and practice; skills in presenting scientific material and arguments in writing and orally, to an informed audience; computational and data processing skills, relating to chemical information and data.

Required chemistry-related practical skills encompass: skills in the safe handling of chemical materials, taking into account their physical and chemical properties, including any specific hazards associated with their use; skills required for the conduct of standard laboratory procedures involved and use of instrumentation in synthetic and analytical work, in relation to both organic and inorganic systems; skills in the monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation thereof; ability to interpret data derived from laboratory observations and measurements in terms of their significance and relating them to appropriate theory; ability to conduct risk assessments concerning the use of chemical substances and laboratory procedures.

Finally, essential generic and transferable competences deal with: the capacity to apply knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information; numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units; information-management competences, in relation to primary and secondary information sources, including information retrieval through on-line searches; ability to analyse material and synthesise concepts; information-technology skills such as word-processing and spread sheet use, data-logging and storage, subject-related use of the Internet; the capacity to adapt to new situations and make decisions; skills in planning and time management; interpersonal skills, relating to the ability to interact with other people and to engage in team-working; communication competences, covering both written and oral communication in both one of the major European languages (English, French, German, Italian, Spanish) and the language of the home country; study competences needed for continuing professional development, in particular the ability to work autonomously; ethical commitment.

2.2. The Euromaster® Quality Label

The Euromaster® Quality Label [10] is awarded to programmes involving 90 to 120 ECTS credits, at least 60 of which must be at master's level. Since second cycle studies are much more flexible than first cycle ones, it is neither necessary nor advisable to list areas of subject knowledge, which the programme should cover. According to the needs of the institution, such programmes will be either broadly-based or specialised. The master's thesis, however, should carry at least 30 ECTS credits. The primary aim of the qualification is to provide a second cycle degree which will be recognised by:

- Other European institutions, as being of a standard, which will provide automatic right of access (though not right of admission) to chemistry doctoral programmes or third cycle courses;
- Employers, as being of a standard which fit the graduates for employment as professional chemists in chemical and related industries or in public service;
- The *European Association for Chemistry and Molecular Sciences*, as being sufficient to allow the graduates to obtain the status of *European Chemist*.

The following aspects are considered in the Euromaster® Label:

- Learning outcomes, including subject knowledge, as well as abilities and skills – chemistry-related cognitive abilities and skills, chemistry-related practical skills, generic and transferable competences;
- Modularisation of courses and contents;
- ECTS credit distribution;
- Student workload;
- Mobility;
- Methods of teaching and learning;
- Assessment and grading;
- Quality assurance**.**

Although the institution can define the appropriate subject knowledge for its own individual degree programme, abilities and skills are carefully monitored, since students may come from a different undergraduate background.

Indispensable chemistry-related cognitive abilities and skills encompass, in addition to those requested for the first-cycle level: ability to demonstrate knowledge and understanding of essential facts, concepts, principles and theories relating to the subject areas studied during the master's programme; ability to apply such knowledge and understanding to the solution of qualitative and quantitative problems of an unfamiliar nature; ability to be able to adapt and apply methodology to the solution of unfamiliar problems.

Further chemistry-related practical skills considered necessary include: competences required for the conduct of advanced laboratory procedures and use of instrumentation in synthetic and analytical work; ability to plan and carry out experiments independently and be self-critical in the evaluation of experimental procedures and outcomes; ability to take responsibility for laboratory work; ability to use an understanding of the limits of accuracy of experimental data to inform the planning of future work.

Finally, essential generic and transferable competences deal with: study skills needed for continuing professional development; ability to interact with scientists from other disciplines on inter- or multidisciplinary problems; ability to assimilate, evaluate and present research results objectively; advanced communication competences in a second European language, along with the mother tongue.

2.3. The Chemistry Doctorate Eurolabel®

As a framework for a third cycle qualification, the Chemistry Doctorate Eurolabel® [11] interests institutions which have introduced structured doctoral programmes in chemical sciences or interdisciplinary topics based on chemistry. It is fostering quality assurance for doctoral degrees in chemistry, is promoting mobility at a global level, and is guaranteeing harmonisation and transparency towards the research community and the labour market.

The following aspects are considered in the Chemistry Doctorate Eurolabel®:

- Fitness for purpose;
- Entry to the programme;
- Length of studies;
- Study programme structure, *i.e.* coursework and credits considered in the widest possible sense;
- Teaching and training in generic competences;
- Transcripts;
- Graduate schools;
- Supervision;
- Examinations;
- Assessment;
- Quality assurance.

The relevant *Budapest Descriptor* illustrates the goals of a doctoral programme in the chemical sciences, and applicants are asked to provide a statement defining the aims and the profile of the programme; and describing the skills and competences, which the graduate will have developed at the end of the programme. The accreditation process is then designed to find out whether the programme as set out in detail in the application is suitable for the purpose for which it is designed.

The means used for acquiring key competences – during research work or in the context of specialised workshops and course units – are given an important place in the frame of the Quality Label, since they are crucial for entering the labour market; and are addressing environments candidates are likely to meet during any forthcoming career connected to their qualifications. They presume original, independent and critical thinking, and read as follows:

- The planning process – objectives, strategies, policies, decision making;
- The structure and process of organising – authority *vs*. self-contained work, organisational flexibility, adaptability to novel situations, time management;
- The management of human resources – qualifications *vs*. requirements, orienting new team members, team building, organising individual tasks and duties, formulating motivation strategies;
- The management of information – analysis, evaluation, synthesis and selection of complex concepts and facts;
- The communication process – communication skills (including presentation techniques, language skills, writing of proposals and reports); tutoring and training skills; ability for knowledge transfer and interaction under multilingual conditions with peers, audiences & panels, the scholarly community and society in general;
- The development process – internal and external training, handling innovation;
- The management of financial issues – facing budgetary and market-oriented questions, dealing with budgetary restrictions;
- The process of controlling and assessing quality;
- Social responsibility and ethics.

In order to better align further with the European bodies awarding Quality Labels, the European Chemistry Thematic Network Association is a founding member and holds the vice-presidency of the European Alliance for Subject-Specific and Professional Accreditation and Quality Assurance (EASPA) [12].

By May 2012, 68 Eurobachelor® and 31 Euromaster® Labels, along with 2 Chemistry Doctorate Eurolabels®, have been awarded to 56 institutions and 4 consortia coming from eighteen European and two non-European countries, the latter being Morocco and Kazakhstan.

3. Virtual Educational Structures: The Virtual Education Community for Chemical Sciences

The Virtual Education Community for Chemical Sciences is aimed at supporting studies in chemistry by implementing a series of electronic means permitting interactive on-line access to teaching units/modules and tests. Target groups within the initiative encompass secondary, vocational and tertiary education students, as well as any type of adult learners. The overall procedure is consistent with the European Union policy to harness Information and Communications Technologies for developing innovative education and training practices, improving access to all levels of education and training, and helping develop advanced management systems [13].

The Committee on a Virtual Education Community is pursuing three interlinked activities, namely a Repository of Distributed Learning Objects, the EChemTest® – a European on-line self-assessment and assessment tool evaluating knowledge and competences in chemistry and related disciplines at several educational levels –, as well as regular publication activities. The latter include a bi-monthly *Newsletter* [14] and the recently founded electronic magazine for virtual innovation research teaching and learning communities V*IRT&L-COMM* [15].

3.1 Repository of Distributed Learning Objects

The concept of access to and detection of educational resources in the distributed Internet environment refers to an open knowledge management model. Based on the progress made in the deployment of the recently launched *European Grid Infrastructure* [16], the Committee on a Virtual Education Community established a Repository of Distributed Learning Objects exploiting organised collections of digital resources that may be constantly used to support learning. Scope of the Repository is to store, identify, localise and reuse educational information in chemical sciences.

Developing a grid-based Repository involved implementation of an innovative management system for Distributed Learning Objects. Main features of the new platform G-LOREP® (Grid Learning Objects REPository) are:

- Focusing on large communities, a fact implying a complex and distributed nature of the repository;
- Adopting an efficient mechanism of filing and retrieving distributed information;
- Exploiting the innovative features of the *European Grid Infrastructure*.

The architecture chosen consists of:

- A server bearing a Content Management System, which takes care of Repository management activities at backend-level, and a server providing – through a web portal – various services to clients at frontend-level;
- A set of clients requiring available services;
- A network allowing clients to use existing facilities after authentication;
- A virtual organisation providing access to remote file systems storing the Learning Objects.

For the time being, two major subject areas are addressed in the Repository of Distributed Learning Objects – computational chemistry and chemistry applied in the preservation of material cultural heritage.

3.2. EChemTest®

EChemTest® is an electronic test developed by the European Chemistry Thematic Network Association, and aimed at evaluating knowledge and competences in chemistry. It has a wide-ranging impact over chemistry-related studies, both formal and informal, in Europe and outside its borders.

By taking the test, the professional is assisted in his work, and is motivated in starting a formal course or taking a national examination; the student is self-assessing or assessing his knowledge of chemistry in a European frame, and is evaluating his understanding of scientific notions in a foreign language; and the citizen is pursuing high-standard life-long learning.

EChemTest® is organised in assessments, typically consisting of thirty questions and having a time limit of sixty minutes. The questions are automatically and randomly selected from specific large EChemTest question banks, covering the *European Core Chemistry* [17] – a compilation of common core topics required in all European chemistry curricula – at three different levels, equivalent to the end of compulsory education, the beginning of university studies, and the end of the core chemistry syllabus in organic, inorganic, analytical, biological and physical chemistry, as well as in chemical engineering (*ChemEPass*® project [18]). Moreover, assessments are provided at a higher level, equivalent to the end of second cycle studies in specialised chemistry areas, such as computational chemistry, advanced synthetic chemistry, and chemistry applied in cultural heritage preservation.

EChemTest® data banks are available in a number of European languages, *i.e.* English, Finnish, French, German, Greek, Italian, Polish, Slovene, and Spanish. Moreover, the multilingual test is being expanded to more professional areas on the basis of a co-operation with the *European Institute for Measurements and Reference Materials – TrainMic*® project [19].

In addition to on-line self-assessment opportunities, EChemTest® examinations are offered under controlled conditions in fully equipped authorised Testing Centres and Testing Units, monitored by an educational supervisor and employing trained administrators. Candidates register on-line and apply for a personal account, in order to be connected *via* a web browser to the server, where all question banks and assessments are uploaded. When entering the personal name and password into the log-in page, a list of all available assessments appears on the screen. Participants select the desired examination, and are automatically directed to the secured environment of the test. At the end of the session, examinees submit their answers to the server, to be saved and scored; and the final total score appears on the screen with feedback for each question. A comment box is also available for formulating remarks. Successful examination in a Testing Centre permits applying for the *European Chemistry Certificate*, issued by the European Chemistry Thematic Network Association.

Testing Centres are already established at the following institutions:

- Technical University of Vienna, Austria;
- University of Helsinki, Finland;
- CPE Lyon, France;
- Aristotle University of Thessaloniki, Greece;
- Ëtvös Lörand University of Budapest, Hungary;
- University of Perugia, Italy;
- Jagiellonian University of Krakow, Poland;
- Ljubljana University, Slovenia;
- Complutense University of Madrid, Spain;
- University of Amsterdam, The Netherlands;
- University of Reading, United Kingdom.

To these are further connected Testing Units at:

- Fresenius Applied University, Idstein, Germany;
- Universities of Oulu and Lappland, Finland;
- University of Ioannina, Greece;
- Sofia University of Chemical Technology and Metallurgy, Bulgaria;
- Sidi Mohamed ben Abdellah University of Fez, Morocco;
- Tshwane University of Technology, South Africa.

4. Intense Learning Structures: The Intensive Schools on Chemical Sciences and on Key Competences for Scientists

Intensive Schools are a means for transmitting state-of-the-art specialised knowledge and skills, while at the same time enhancing multinational interactions and intercultural communication at student and lecturer level, developing linguistic skills specific to a subject area, and promoting networking initiatives. In this context, Intensive Schools are most appropriate for addressing topics at the interface of scientific disciplines, and for introducing the acquisition of competences essential for entering the labour market.

Hence, they should actually concern any transnational educational body active in harmonising learning outcomes, fostering transparency and facilitating mobility.

The European Chemistry Thematic Network Association implemented a number of relevant initiatives, co-ordinated by the Committee on Intensive Schools and Student-Centred Activities, and closely connected to the outputs and products of the Virtual Education Community for Chemical Sciences. A first series is focused on chemistry applied in cultural heritage preservation, and a second is dealing with key competences.

A multinational team of experts – typically partners in Erasmus [20], Erasmus Mundus [21] or Tempus [22] educational projects – are delivering theoretical lectures, problem-solving classes and hands-on experimental exercises to students originating from the whole of Europe, most Arab Mediterranean or Gulf countries, the ex-Soviet Union, and occasionally Ethiopia, Japan, Brazil, Mexico, and the U.S.A. Attendees are selected on the basis of an on-line contest, dealing with preparing a poster and authoring an abstract on a given scientific article; as well as with taking EChemTest assessment sessions.

e-Learning possibilities for self-paced pre- and post-School use are available to candidates. They consist in evaluated on-line didactic and self-assessment material, integrated in the Repository of Distributed Learning Objects.

The Schools are held in English or follow a bilingual scheme – *e.g.* English/French or English/Spanish. In order to address linguistic issues, students are offered the possibility to follow structured preparatory specialised on-line courses on language and terminology [23]; while systematic relevant classes and officially recognised examinations [24] are organised during the Schools at levels B1, B2 and C1.

The Intensive Schools on Conservation Science [25] deal with the physicochemical aspects of cultural heritage preservation, and mainly address second and third cycle science students, as well as active professionals, wishing to acquire a solid knowledge on the ways natural and material sciences are applied in the safeguarding and authentication of tangible works of art.

General sessions of the Schools take place every July and welcome approximately fifty students for ten to twelve days. They have been held in Thessaloniki, Greece (2006 and 2009); Palermo, Italy (2008); Teruel, Spain (2010); Istanbul, Turkey (2011); and Evora, Portugal (2012). Thematic sessions last a week, and already include Mortars and Binding Materials (Fez, Morocco, 2010); Metallic Artefacts (Genoa, Italy, 2011); Conservation and Rehabilitation Methodologies (Marrakech, Morocco, 2012); and Ceramics (Castellon de la Plana, Spain, 2012). Study material consists in on-line modules prepared by the teaching staff and further experts [25].

The Intensive Schools on Key Competences for Scientists are structured as interactive workshops and problem-solving classes. Great care is taken to integrate non-academic lecturers, in order to prepare students as much as possible for the conditions encountered in the labour market. The generic and transferable competences required for awarding the European Quality Labels in Chemistry [27] form the core learning outcomes of the Schools.

Recently launched as three- to four-day events, structured along the pattern of on-line opportunities for both content-specific and linguistic preparation [28], the 2012 School editions include Castellon de la Plana, Spain; Avignon, France; Evora, Portugal; and Thessaloniki, Greece.

5. Profile-Raising Activities: Endeavours Enhancing the Attractiveness of Chemistry

In recent years chemistry has often been blamed for disturbing the welfare of Earth. Confronting this highly objectionable attitude, the European Chemistry Thematic Network Association undertook the task of enhancing the attractiveness of the discipline. In fact, both the public at large and youth are approached in a multifaceted way, encompassing a variety of contests, as well as the bilingual (German/English) web site ChemInsight® [29], which has been one of the first European platforms elucidating the role of chemistry in everyday life at transnational level. The site has recently been evaluated from an educational point of view, and is now being upgraded into a highly effective tool – a European web portal supporting the image of chemistry in a scientifically accurate and pedagogically appealing manner.

A series of competitions and events, co-ordinated by the Committee on Intensive Schools and Student-Centred Activities, is inducing students to a more active involvement in chemically oriented open initiatives, or is systematically revealing interesting aspects of chemistry.

In this frame, EChemTest® Testing Centres are annually organising national/regional contests among high school pupils aged 15 to 18 [30]. Examinations are held both in the mother tongue and English, and all district winners are invited to compete in the frame of a largely publicised event, and be awarded European distinctions.

A pronounced impact – even outside European borders – is conferred to the Awareness of Chemistry contest [31]. The underlying intention is to impel young people understanding chemical issues and processes to the level of being able to interpret them for the general public, either as a simplified but complete presentation or in an artistically engaging form. Thus, candidates are asked to develop original products presenting solutions that chemistry can provide to any sector of modern society. Juries of experts are nationally selecting the best contributions, which are subsequently submitted to open voting: the winners are awarded European distinctions.

A further competition, or rather happening, is the Magic Show [32], namely sets of experiments combining unexpected or striking procedures and results to a precise scientific background. The Show is held at least once a year in the frame of large meetings or conferences; and is operated by various student groups from all over Europe.

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Localization, Regionalization, and Globalization of Chemistry Education

Mei-Hung Chiu

National Taiwan Normal University, Graduate Institute of Science Education, Taipei, Taiwan, mhchiu@ntnu.edu.tw

Abstract
More and more countries are paying attention to the relationship between curriculum standards and student learning outcomes on international assessments such as the Trend of International Mathematics and Science Study (TIMSS) and the Programme of International Students Assessment (PISA). In today's global society, no country can afford for its citizens to be educationally marginalized. In this paper, I explain the need for globalization of chemistry education specifically and outline what can be done to promote this globalization in a manner that both motivates students and links international students together.

Learning in Chemistry
Over the past three decades, chemistry educators have become increasingly aware of the connection between students' preconceptions of natural and physical phenomena and their successful leaning of science. Numerous studies have shown that students from different countries possess similar patterns and sources of alternative conceptions when it comes to learning chemistry. Taking the most fundamental topic in chemistry, nature of matter (structure and behavior), as an example, 13-16 year-old students considered matter as a homogeneous substance, composed of units of "small atoms," instead of viewing matter as a system of particles (Renstrom, Anderson, & Marton, 1990). Additional studies with high school students have demonstrated that even at this level students have difficulty using the particle model of matter to provide scientific explanations (Franco & Taber, 2009), describing macroscopic character of matter (Johnson & Papageorgiou, 2010), and using molecular weight to determine the position of gas diffusion (Chiu, 2007; Liang, Chou, & Chiu, 2011). This basic misconception regarding the nature of matter was first found by Nussbaum and Novick (1982) and supported by later research carried out in different countries demonstrating that even older high school students consistently revert to a continuous model of matter instead of the particulate model (e.g., Johnson & Papageorgiou, 2010; Nakhleh, Samarapungavan, & Saglam, 2005). Even when such misconceptions are the target of remediation, German seventh and eighth graders still had difficulty understanding how particles build matter (Beerenwinkel, Parchmann, & Gräsel, 2011).

Although there are similarities in students' chemistry misconceptions across countries and cultures, each region's language can also uniquely contribute to such misconceptions. For instance, Herron (1996) argues that the meaning of some words in chemistry differs from the meaning of those same words in everyday life. Sometimes language in chemistry can even conflict with how that same language is used outside of chemistry. Students need to learn the language of chemistry within chemistry contexts. In one study, 36% of Chinese sixth grade school students thought a solution of sodium bicarbonate and acetic acid was neutral because it involved a neutralization reaction. The Chinese characters for neutralization are: 中和. The first character means middle so Chinese students mistakenly interpret the term, neutralization, to mean a pH of 7 (Huang, 2004 as cited in Chiu, 2007). As much as 25% of Chinese junior high school students share this same misconception. Studies of Chinese students show that these students tend to take the superficial meanings of the Chinese characters as the scientific meanings of the terms in chemistry. Mercury in Chinese is written as: 水銀 where the first character means water and the second character means silver (Hsu, 2004). Studies have shown that Chinese students consider mercury either a liquid or a metal due to the literal meanings of the Chinese characters that comprise the term, mercury. Similar results were found in Lin and Chiu (2009). This type of language effect should be carefully taken into account when instructors teach the terminology and concepts of chemistry. Language is a double-edged sword. Sometimes it helps students understand scientific concepts in a more explicit manner, and sometimes it hinders students' understanding. Recognizing and bringing to the forefront these instances where language can be confusing for students is necessary for successful science teaching and learning.

Johnstone's (1993) famous triangle graphically depicts the links between the macroscopic, molecular (micro), and symbolic levels of science learning and highlights the increasing difficulty students experience going from one level to the next. Mahaffy (2006) added an additional perspective (the human element) to this triangle in order to situate chemistry within an authentic context, and in so doing turned the triangle into a tetrahedral. To further extend this model, I advocate that we change the "molecular" or "sub-micro" to "meso" for representing the linkage between macroscopic and microscopic world rather than the use of a subordinate category (sub-micro) for "microscopic". I also added language as another factor influencing students' understanding of complex science concepts, thus changing the model to a pyramid (see Figure 1).

Global Impact of PISA and Curriculum Standards
Given the widespread and tenacious nature of students' alternative conceptions in chemistry, one has to wonder what effect national and even international curriculum standards could have on such misconceptions.

Conversely, if there are no national curriculum standards for a particular nation, then what measuring stick does that country use to evaluate its students' performance in science learning? In the following section, I highlight examples from countries that took action in light of unsatisfactory results on international assessments and relate these initiatives to the need for national and international standards in chemistry.

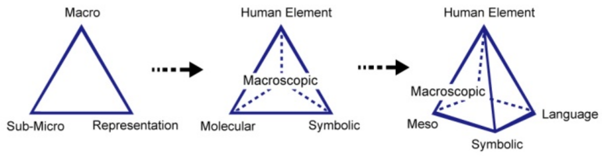

Figure 1. Factors influencing chemistry learning

Countries ranked high on international Science, Technology, Engineering, and Mathematics (STEM) assessments tend to have national science standards (Chiu, 2006). This result is consistently found across studies of TIMSS and PISA outcomes. These countries include Hong Kong, Japan, Korea, Singapore, and Taiwan. This suggests that the presence of national standards as gate keepers (providing guidelines) to assure a minimum level and quality of education impacts the results of international assessments. It became apparent to many researchers and policy makers from different countries that establishing national curricula is an emerging action to take if one country wants to be economically, culturally, and educationally competitive in the world. Such action has been taken across continents. For instance, the 1999 PISA results shocked German policy makers and in 2003 the German National Standards of Education (Nationale Bildungsstandards, NBS) were set into practice as the country's achievement standards. At first, Germany developed achievement standards only for the main subjects (mathematics and foreign language) and then followed up with standards for the science subjects (biology, chemistry, and physics; See Schecker & Parchmann, 2007). These new standards elucidated for all educators exactly what German students were expected to be able to do at the end of a certain grade. Austria too began to develop and implement educational standards (Weiglhofer, 2007).

In Australia, there are two levels of standards for science education. National standards are assessed on a country-wide scale while state/territory standards are assessed by different methods overseen by each state's accreditation authority (Hafner, 2007). Australia's *National Goals for Schooling in the Twenty-First Century* (MCEETYA) aim to provide a measurement framework for Australian state and territory governments to affirm a commitment to national reporting of comparable educational outcomes. Along this line, Key Performance Measures (KPM) guide the development of the national goals. According to Hafner (2007), the KPM were not only influenced by a national review completed by Goodrum et al. (2001) but were also influenced by the PISA assessment in science. The Minister's report of 15-year-old achievement in science is to be reported as the percentage of students achieving at or above the Organisation for Economic Co-operation and Development (OECD) mean score of the scientific literacy assessment of the PISA (Hafner, 2007).

Treagust and Chandrasegaran (2011) stated that due to an absence of a formal science syllabus in Australia, "it is only possible to deduce a limited number of chemistry topics that are common to all science curricula" (p. 201). Others claim that although Australian pupils perform comparatively well on international assessments (such as TIMSS and PISA), there is large variation within the pupil sample with mean achievement scores being highest in metropolitan areas and lowest in regional, remote, and very remote areas (Thompson & De Bortoli, 2008, cited in Treagust and Chandrasegaran, 2011). As educators, researchers, and policy makers we must consider if any policy can eliminate such discrepancies in student performance and generate equality in educational opportunities and learning outcomes.

In addition, the United States does not have a national science curriculum. In 1996, *National Science Education Standards* was launched for the first time to set standards for content, teaching, assessment, and professional development. *National Chemistry Education Standards* was also written. Although no mandatory implementation has been enforced, many states and researchers have started to consider the main themes addressed in these standards. A more recent framework for K-12 science education was reported by the National Research Council (2011) and identifies core ideas for physical sciences at the end of grades 2, 5, 8, and 12, including structure and properties of matter, chemical reactions, nuclear processes, and energy. This new framework aims to help students see how science and engineering are instrumental in addressing major challenges that confront society today. Although not all students will choose science-related careers, these standards presuppose that all students need to be motivated and inspired to better understand the contribution of science, engineering and technology in their lives.

Ranked as the top country in PISA, Finland teaches chemistry as a separate subject at grades five to six (ages 11-12; Lampiselkä, 2010). Lavonen and Laaksonen (2009) claim that three principles present in the educational policy of Finland contribute to Finland's success on the PISA. First, Finnish educators who teach science subjects (physics, chemistry, and biology) are "highly specialized and familiar with the epistemological, ontological and methodological issues concerning their subject" (p. 938). Second, the focus on educational equality increases achievement of low-performing students and develops their self-efficacy. Finally, key stakeholders from primary education through university are not implementers of decisions but partners in decision-making. Finland is not following a standards-based education policy nor following a consequential accountability system for schools according to student success/failure rates, standardized tests, or external evaluations.

In 2004, the Finnish National Board of Education introduced the *National Core Curriculum for Basic Education* to emphasize practical work as an essential approach to primary chemistry education. Increasing decentralization has brought many opportunities to teachers and students. Despite support for practical work and contextualized learning in research and policy documents, classroom emphasis, particularly in Asian countries, remains

Currently, there is no single set of standards or curriculum for all countries to follow. What is successful in one country might not be effective in other countries. Certainly, each country is unique and influenced by its history, culture, and societal conditions and expectations. However, what should students across the globe learn about chemistry in elementary education, secondary schools, and universities in order to face the challenges of global citizenry? What should be covered in school practice to prepare our pupils for healthy living and a healthy planet? What should be the minimum content requirements and competencies for chemistry education across the globe? What competencies do chemistry teachers need to possess themselves and develop in their students?

Globalization of Chemistry Education

Globalization is not a new movement in our era. But there remains little research examining the impact of globalization on the areas of K-12 science classrooms, science teacher professional development, and science education research (Martin, 2010). This also holds true for chemistry education. Although Fensham (2008) argued that PISA reveals little about what students are experiencing day by day with their teachers in their science classrooms and how this can be improved upon, PISA findings do shed some light on our understanding about the science competence level present in different countries as well as the impact of PISA on education policies.

To some countries, it seems that the globalization movement starting from economic and business areas has slowed with only minor impact on science or chemistry education. For instance, Choi et al. (2011) stated that even though South Korea is aware of the importance of cultivating students to be creative and to appreciate diverse cultures and values, their national science curriculum does not explicitly represent the idea of globalization and global citizenry. Choi and his colleagues also addressed how scientific literacy is needed from personal to global perspectives and they put high value on literacy from the personal context, societal context, and to the global context with increasing awareness of habits of mind, metacognition, and self-direction while considering science as a human endeavor. Cheng (2011) also mentioned that instead of introducing chemistry decontextually, the curriculum should try to bring chemistry into pupils' daily experience thereby making it more relevant. The well-known contextualized chemistry learning by Parchmann and her colleagues (2006) illustrates the importance of generating a learning context where students can apply their knowledge of chemistry in solving problems of daily living. In Australia, "The development of chemistry courses largely maintains the structure of a typical chemistry syllabus with more emphasis on differentiating macro and sub-micro properties rather than development to a context-based approach" (Treagust and Chandrasegaran, 2010, p. 204). Germany has pushed for more context-oriented teaching approaches but in reality these have yet to reach the majority of classrooms (Nentwig, Roennebeck, Schoeps, Rumann, & Carstensen, 2009). The slow impact of the contextualized chemistry learning movement is also observed in Asia and may be attributable to the emphasis on content-based instruction, high risk high school and university entrance examinations that tend to be decontextualized, and the success of these countries on the TIMSS and PISA. Apparently, reflections and emerging needs are not necessary to influence decision makers in reforming the system. On the contrary, some western countries reacted to the outcomes rapidly and took actions to move the educational enterprise to elicit learners' literacy in different school subjects. These findings reveal the limited impact of the learning in context movement and the shortcomings and challenges of contextualized learning for linking chemistry concepts with daily life.

To close this section, I would like to discuss whether there exist significant differences among participating countries from different continents. In many reports, we tend to use countries/regions as the comparative units. Here, I try to use continent as the unit of analysis to see what patterns we have across the world. What if we take all the participating countries on each continent into consideration and use the OECD Human Development Index (HDI) as a reference to compare different continents. The results show that there are no significant differences among different continents if HDI is larger than .8 which is defined as developed countries. In other words, as long as a country is ranked as a developed country, it is not significantly different from other developed countries in science in PISA (See Table 1 below). This holds true for developing countries too. But, there is a significant difference between developed and developing countries in terms of student performance in science on the PISA which suggests that developing countries need more attention from developed countries to support their educational growth.

Table 1. Students' performance on PISA 2006 science by continents.

	PISA 2006 Science	
	HDI > 0.8	**HDI < 0.8**
Asia	491.57	392.86[a]
Europe	503.00	445.33
North America	511.50	407.50[b]
Oceania/Australia	528.50	N/A

Note a: value for Asia & Africa combined; b value for Central and South America (North America N/A)

Similarly, across continents, we do not find significant differences among developed countries in terms of student performance on science or chemistry in TIMSS 2007 (see Table 2). This holds true for developing countries too. But, again, there are significant differences between developed and developing countries on each continent. More support in the form of resource people, supplies, and programs like the Flying Chemistry Program sponsored by IUPAC (see http://old.iupac.org/standing/cce/FCP.html), are necessary to promote and help equalize student learning outcomes and teacher instructional quality in developing countries.

Table 2. Eighth grade students' performance of science and chemistry on TIMSS 2007 by continents.

	8th Grade TIMSS 2007			
	Science		Chemistry	
	HDI > 0.8	HDI < 0.8	HDI > 0.8	HDI < 0.8
Asia	500.89	441.93	498.56	441.50
Europe	506.08	480.50	499.67	482.50
North America	527.00	N/A	511.57	N/A
Central & South America	N/A	402.00	N/A	398.50
Africa	N/A	386.83	N/A	402.33
Australia	515	N/A	505.00	N/A

Alignment of Curriculum Standards for Localization, Regionalization, and Globalization

If building up a framework for chemistry education is important for a nation, how about for the international community? What should we do in school practice to prepare future generations to be contributing global citizens? To answer these questions, we might need to set the goals for each level: national, regional, and global first and then align them. Furthermore, implementation protocols that are most likely to lead to goal success must be determined. Professional development programs to elicit teachers' competence in pedagogical content knowledge should be designed and offered by different organizations (such as the Ministry of Education of a nation and international organizations like IUPAC). A pictorial representation for contents of goals, standards, and possible strategies is presented in Figure 2. Although there is no one size fits all solution, Figure 2 depicts potential elements of globalization of chemistry education. In terms of geography, Figure 2a shows the relations among countries, regions, and the world. Figure 2b shows the interaction between countries, their relations within a specific geographical region, and the center is the interaction among the countries and regions. For each region, countries might share similar cultural, societal, educational, and historical features that they could use to bridge educational experiences and expectations. However, in considering international standards for chemistry education, we have to also consider the values, expectations as well as the limitations of each country and then find the common core literacy for all global citizens. Figure 2, proposes the directions for developing international standards for chemistry education.

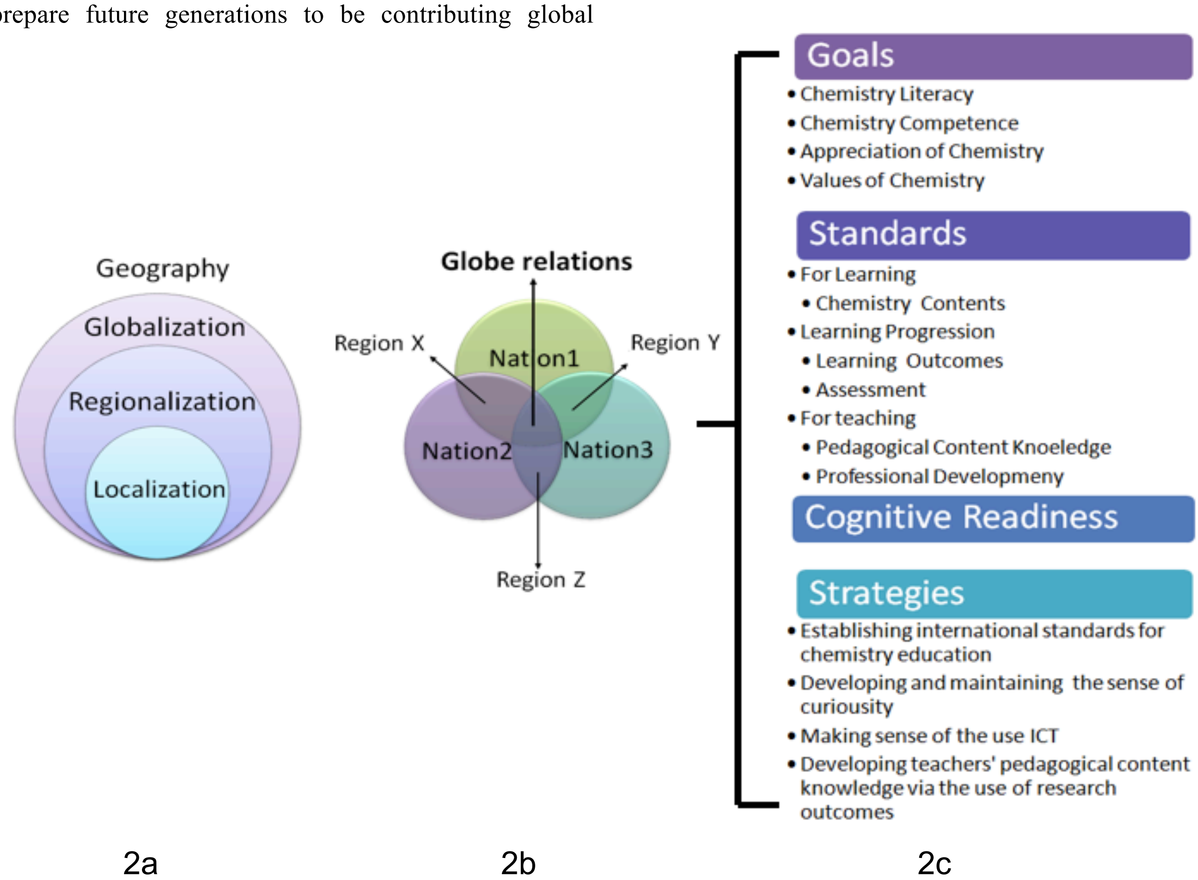

Figure 2. The framework for international chemistry education standards

In short, a paradigm shift is called for. To extend De Boer's (2011) push for international science education standards, I call for international standards for chemistry education with explicit elements not just to assure that all pupils have high quality chemistry education, but also to best prepare our pupils to face the rapidly changing world. Therefore, there should exist a higher level or larger organization to initiate a program to investigate what the international standards for chemistry education should be in order to help all countries-including developing countries-improve chemistry literacy and competence for a better life today and tomorrow.

Strategies for local/national and global demands

International studies on science achievement by different age groups (TIMSS for grades 4 and 8, and PISA for 15 year old students) from different countries all over the world highlight potential issues in chemistry education. These results point to areas for immediate focus to strategically improve students' chemistry literacy. I consider the answers to these questions in the following section

An Emerging Need for International Chemistry Education Standards (ICES)

As countries across the world are moving closer and closer in terms of their educational objectives, what are the basic competencies in chemistry that need to be fostered in the next generation? I would like to propose three pillars that should be considered in developing international chemistry education standards. They are content, process, and appreciation of science. As for content, big ideas (or core concepts) should be identified through a broad view to match global needs, such as atom and matter, structure of molecules, system of chemical reactions, sustainability in chemistry, green chemistry, energy, fuel, and climate change. Second, students must be taught the process for scientific enterprise such as inquiry, problem solving, reasoning, and making argumentation in a context that is related to their daily life. Finally, students have to develop or to motivate their interest in chemistry and appreciation for the value of chemistry in our daily lives. Along the same line, developing teachers' expertise in content specific knowledge and pedagogical competence is essential for effective chemistry.

Building the connection between high school and university

To empower teachers' expertise in pedagogical content knowledge in chemistry, bridging the gap between research and practice is essential. In 2006, the National Science Council in Taiwan launched its High Scope Program (HSP) for the first time to bridge the gap between theories in science education and practice in high schools. The first-phase of the HSP (HSP-I) was a five-year program spanning 2006 to 2011; the second-phase (HSP-II) is a three-year program which has been in operation since 2011. For HSP-I, there were 28 high schools and vocational schools involved in curriculum design in the areas of energy, material science, biotechnology, environment, and nanotechnology. Thousands of science teachers were included and the collaboration extended to include language teachers and social science teachers. A total of 38 HS-Ⅱteams, including 53 high school and vocational schools, aimed to design inquiry-based and innovative science curriculum modules. The topics included medicine and health care, biotechnology, green energy, high-end agriculture techniques, cloud computing, and smart green buildings (also see details on http://w1.ceels.org/highscope/web/modules/tinyd0/index.php?id=9). The HSP was meant to use the "bottom-up" approach to stimulate teachers in high school and vocational schools in implementing innovative design in technology in their teaching as a lifetime learning strategy. With the professional support from universities, high school teachers were supported in taking action in developing new materials and in inspiring students with innovative technology. The National Science Council in Taiwan normally provides funding for research at the tertiary level rather than for secondary schools which are the responsibility of the Ministry of Education.

Developing sustainable motivation and interests in chemistry

With a decreasing percentage of students majoring in chemistry, a continuous effort to motivate and stimulate learners' interest in chemistry is an inevitable action to take and a currently pressing challenge to face. Several possible channels to be considered include inquiry-based curriculum (Krajcik & Sutherland, 2010), linking school learning with industry via collaboration between school teachers and experts in chemistry (e.g., Popularity and Relevance of Science Education for Scientific Literacy, a close cooperation with science educators from several countries sponsored by the EU), learning chemistry in context (Parchmann, Gräsel, Baer, Nentwig, Demuth, Ralle, & the ChiK Project Group, 2006). All these approaches could allow researchers and practitioners to understand what has been learned and what has been lost.

Global experiments through international organizations

The successful Global Water Experiment (GWE) was initiated in 2011 to celebrate the International Year of Chemistry (see http://www.chemistry2011.org). Since launching the Global Experiment on World Water Day in March 2011 in South Africa, 128,330 students and 2,354 teachers (as of 1 April 2012) from over 80 countries have participated. The numbers of students and teachers are still increasing (Martinez & Sigamoney, 2012). This opens a great avenue for students, researchers, and educators to interact with others both locally and globally, to broaden their views of chemistry, and to echo the reform of learning chemistry in context. The design of the global activities should be easy to access by all students across the globe. Through this global experiment, students not only gained more understanding about the content and value of chemistry, but they also increased their interest and motivation in learning chemistry and the public's understanding about how chemistry plays a role in our lives.

Identify the big ideas (key concepts) to be learned for different global citizens

To better understand how we could educate each individual from K to 12 and even beyond, an explicit and systematic infrastructure of key competencies should be expected to guide the educational system. Along the same line, there are three directions to be considered. First, the big ideas should be designed and applied for K-12, university/college students and the public for the sake of improving citizens' lives and keeping up with the rapid changes around the world. Second, not only do we need to identify the big ideas to be learned (and taught), but we also have to explicitly state what the learning outcomes are in order to maintain accountability of the educational quality. At the local level, learning outcomes could help teachers to shape their teaching agenda to bridge the gap between their anticipated performance and actual outcomes of their students. At the global level, it moves school curricula from conventional ways of teaching to social-political action and social responsibility to change the world with chemistry.

From research collaboration to dissemination of research finding

Domestic, regional, and international conferences are the common means for researchers and educators to share and distribute research findings in chemistry education particularly. For instance, the Network of Inter-Asian Chemistry Educators (NICE) was initiated by Taiwan, Korea, and Japan in 2006 and held biennially in different countries. NICE has experienced a dramatic increase in the number of participants over the past few years. Experiences in education in one country can contribute to the teaching and learning in another country. Of course, limitation of cultural and societal factors should be taken into account when the experiences and policies are implemented. At the global level, the International Conference on Chemical Education (ICCE) sponsored by IUPAC is held biennially to allow researchers to interact and to share experiences in teaching chemistry.

However, going beyond participating in conferences on chemistry education, developing mutual interests in conducting research across countries is valuable in broadening ourselves, our teachers, and our students' views about chemistry. As Chiu and Duit (2011) pointed out, international cooperation between science [including chemistry] educators in addressing the globalization of science education research is still a challenge and should be promoted in order to integrate the richness of different views of science [chemistry] education in the various cultures around the world. In addition, school teachers tend not to attend academic conferences on a regular basis, it is the researcher's responsibility to transform research findings into practical documents in order to change the school climate. This research-based approach needs more effort by researchers.

In sum, this article makes a general call for the need for international standards for chemistry education, to promote international collaborations for chemistry education, and to emphasize the appreciation of chemistry by people across the globe.

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A Discipline Network for Chemistry: The UK Experience

Tina Overton

Department of Chemistry, University of Hull, Cottingham Road, Kingston upon Hull, HU6 7RX, t.l.overton@hull.ac.uk

Abstract
The UK benefitted from a network of discipline-focussed teaching and learning support centres for over 10 years before they were disbanded in 2011. This paper discusses the features that made the centres so successful and provides advice for those setting up a similar endeavour network.

Introduction

In January 2000 the higher education funding councils for England, Wales, Scotland and Northern Ireland came together to establish the Learning and Teaching Support Network (LTSN). The LTSN comprised 24 Subject Centres and a Generic Centre. The Generic Centre was co-located with a small senior management team at the LTSN headquarters based at the University of York. The 24 subject centres were located in academic departments across the United Kingdom. Funding had been awarded to establish the subject centres through an open bidding process. The contracts for the subject centres bids were awarded to individual academics or small teams who already had established reputations in the teaching and learning of their disciplines.

Obviously, 24 centres did not reflect the total number of disciplines taught in universities and there was some coming together of cognate disciplines. The funded centres were; history, archaeology and classics; language, linguistics and area studies; materials; engineering; economics; maths, statistics and operational research; biosciences; social work and policy, sociology. politics and anthropology; psychology; geography, earth and environmental science; information and computing science; English; philosophy and religious studies; dance, drama and music; medicine, dentistry and veterinary science; health science and practice; built environment; hospitality, sport and tourism; business, management and finance; art and design; law; and physical sciences. Chemistry was part of the physical sciences centre which brought together chemistry and physics initially. These two communities were at first sceptical that they had anything in common or to learn from each other but it quickly became clear that they had plenty in common; both being experimental subjects, both having a mathematical basis, both struggling to recruit students in some institutions, and both being predominantly taught in research-focussed departments. Later, forensic sciences emerged as an academic discipline in the UK and this was taken into the work of the physical sciences centre. Forensic science had grown out of analytical science in many institutions and was and is predominantly taught in the less research-intensive institutions.

The overarching aim of the subject centres was to disseminate effective practice in the teaching and learning of their discipline. That aim broadened with time to include raising the profile of teaching and learning and supporting and promoting innovation and good practice. But dissemination always lay at the heart of centre activity. Each centre developed its own priorities based on the individual needs of their disciplines. In the physical sciences there was a strong focus on attracting students into the disciplines, on laboratory work, the use of technology in teaching, assessment and feedback, student-centred pedagogies and developing evidence based practice. Some other centres had very different priorities; for example the centre for social work and policy was very preoccupied with government social policy and regulation of the profession.

Centre Operation

The centres developed a wide range of activities and services. These included face-to-face events, conferences and workshops, publications, funding for teaching development projects, development of a resource bank and a website which became a one-stop-shop for anyone looking for resources or advice on teaching in the physical sciences. The centre also ran major projects on open educational content, undertook research projects often in collaboration with the professional bodies. The work of the centre was promoted in every relevant department in the UK through departmental representatives. These were named individuals who supported the centre by advertising services, events and publications in their own department. Such representatives were present in 98% of relevant departments and also provided a useful network for the centre staff to use to gather information about current issues in their own environments and to bounce ideas off. The centre also developed an extensive opt-in mailing list which reflected membership across all physical sciences departments.

The centres were modestly staffed by a small team of enthusiastic and committed individuals with a can-do attitude. The annual spend on staffing remained less than 50% of the total budget in order to leave sufficient funds to spend on and in the discipline community. All subject centres were led by a Director who was an academic in the discipline with a track record and reputation in teaching and learning. The Directors were typically seconded 20-50% to the centre and maintained a regular academic post for the remainder of their time. Most centres employed a full time manager, who was usually subject specialist, and full time administrative support. Additional academic input was usually provided by part time consultants or advisers or full time academic developers, all of whom were subject specialists. This mix of staff gave the centres academic credibility within their communities.

The physical sciences centre was advised by an Advisory Committee which drew members from academia, professional bodies, employers' organisation and other relevant projects. The role of the Advisory Committee was to advise on strategy and direction and give high level advice and support to the Director. There was also cross-representation on the education committees of the relevant professional bodies.

The Association for Learning and Teaching was established around the same time as the LTSN. The ALT was a professional body for teaching in higher education and conferred Fellowship on its members. In 2005, after a review process, the funding councils decided to combine the ALT and the LTSN. The new organisation became the Higher Education Academy. The professional body role of the ALT was lost but the HEA took on the task of developing and implementing a professional standards framework for teaching and learning and to confer Fellowship on those who met the standards. The subject centres carried on unaltered by this merger. The Generic Centre, however, was not so lucky. The generic Centre had been providing an analogous role to the subject centres but on generic issues, such as assessment and employability. Under the HEA the generic centre disappeared and the size of the head quarters increased enormously, to include a larger management team and institutional functions such as personnel, finance, IT infrastructure etc. The headquarters grew from a small team to an ever-expanding organisation. There was more focus on accountability, evidence and data gathering and inevitably more reporting. The administrative burden on subject centres rose but the basic aims and objectives remained the same. The subject cetres were enjoying excellent reputations within their communities and with professional bodies and were seen as champions for teacing and learning. Many examples of real impact on students and on the careers of academics were readily identifiable. There was good evidence of shifting pedagogies and an increased profile for teaching and learning.

In 2010 the HEA appointed a new Chief Executive and he inevitably reviewed the structure of his new organisation. The HEA consisted of a large headquarters on a science park where staff were contracted to the parent orgasation, and 24 subject centres embedded within acadmic departments, whose staff were contracted to the host university. This looked like a messy arrangement and so the decision was taken to move all activity to the headquarters. In July 2011 the subject centres closed to the bitter disappointment of those who worked in them and to the large number of academics who had benefitted so much form being part of a community with shared interests. At the time of writing, new staff appointed to the HEA are starting to develop activities for physical sciences. I wish them luck and hope that they can bring the established community with them and provide the level of support they previously enjoyed.

Conclusion

In my view the success of the newly formed subject centres was based upon

- Developing a close knit team with a shared ethos
- A proactive, can-do attitude
- Academic credibility by using established practitioners
- The ability to build a community of those interested in teaching who often feel isolated
- Establishing a contact in every relevant department
- As much face-to-face interaction as possible
- Bringing in expertise from wherever it is based
- Encouraging colleagues in universities to join in the work of the centre.

The resources developed by the UK Physical Sciences Centre are still available through the HEA website: http://www.heacademy.ac.uk/physsci/

Attitude toward the Subject of Chemistry in Australia: An ALIUS and POGIL collaboration to promote cross-national comparisons

Xiaoying Xu,[1] Daniel Southam[2] and Jennifer E. Lewis[1*]

[1] Department of Chemistry, University of South Florida, Tampa, FL 33620, United States of America; [2] Department of Chemistry, Curtin University, Perth, WA 6845, Australia; jennifer@usf.edu

Abstract

Networks of educators and researchers that cross international, cultural, and disciplinary boundaries create challenges for comparative measures, even as the network structure invites comparison and collaboration to achieve maximal efficacy. Recognizing that local and contextual issues may impact the interpretation of results, it is important to examine even familiar data when it is gathered in new venues, to ensure that underlying assumptions about the nature of the data remain satisfied. In this example of one such network, Active Learning in University Science, and one such instrument, Attitude toward the Subject of Chemistry Inventory, we explore how using internationally accepted psychometric standards of reliability and validity is important to demonstrate its utility in context before cross-cultural comparison.

Introduction

A collaborative network of like-minded tertiary science educators was formed as part of Active Learning in University Science (ALIUS) (Bedgood, 2008). The nascent project *"Developing leaders of change in the teaching of large university chemistry classes*", funded by the Australian Learning and Teaching Council, focused on capacity building to drive student-centred curriculum design and pedagogy in the discipline (Bedgood, Yates, et al., 2010). The aim was to develop local leadership capacity, by forging partnerships between local and international educators, that would guide sustainable and long-term embedded practice (Bedgood, Bridgeman, et al., 2010). One such student-centred strategy introduced was Process Oriented Guided Inquiry Learning (POGIL), where students work through carefully crafted activities in small groups (POGIL, 2012). The use of POGIL in the classroom has demonstrated benefits to students in terms of content mastery, higher-order thinking skills, metacognition, and teamwork (Moog et al., 2009).

POGIL has been implemented in our large first year chemistry classes at Curtin University by replacing some or all of the didactic lecture presentation with small group work, clicker questions and online mini-lectures in a blended learning environment (McIntyre, 2010). Dissatisfaction with the current student-teacher paradigm motivated our change. We felt a need to improve the attitude of our students toward the discipline by enhancing engagement, and this potential was identified within POGIL. As we seek to encourage others to adopt similar strategies for similar purposes the question arises: are these aims met at Curtin and what tools are available to assess the impact, in these realms, of innovations in the classroom?

Cognition and affect are two domains central to the aims of implementing POGIL at Curtin. To focus on attitude within the affective domain, a short-form eight-item semantic differential instrument, Attitude toward the Subject of Chemistry Inventory (ASCIv2), was chosen as key assessment tool (Xu & Lewis, 2011). ASCIv2 captures responses on a seven-point semantic differential scale to eight items regarding "*intellectual accessibility*" and "*emotional satisfaction*", reflecting the cognitive and affective components of a tripartite attitude framework.

Here we will present preliminary findings from data collection in two POGIL classes at Curtin. Before commencing broader studies we must ascertain whether ASCIv2 will perform, in the local context, within psychometric standards for reliability and validity. Secondly, we can compare the preliminary findings to existing research using the same instrument. Finally, we can demonstrate how networks can demonstrate efficacy through the use of such an instrument and build knowledge internationally about education of science at the tertiary level.

Instrument

Attitude toward the Subject of Chemistry Inventory (ASCI) was originally designed by Bauer to measure students' attitude toward chemistry (Bauer, 2008). ASCIv2 is a refined version that contains only eight items in two subscales, "*intellectual accessibility*" (e.g., how difficult is chemistry?) and "*emotional satisfaction*" (e.g., how comfortable is chemistry?), and performs well from a psychometric perspective (Xu & Lewis, 2011). In this study, ASCIv2 was used to collect data from Curtin students during October 2011. Although the instrument has been used successfully at two different US universities, Curtin students may have culturally-influenced interpretations of the instrument items that are different from those of US students, so it is necessary first to examine reliability and validity evidence for the data obtained at Curtin.

Sample

Curtin students from two different classes participated in the data collection during October 2011. Class I is a second semester general chemistry course undertaken by Science (34%), Engineering (59%) and double degree (6%) students. The students from Science undertake this course in the first year, second semester of their studies, while those from Engineering and double degrees primarily undertake it in their second year. This class is predominantly male (80%) and from diverse cultural and linguistic backgrounds from Asia, Africa and the Middle East, in line with the general student population at Curtin. Class II is a second semester, first year organic and biological chemistry course undertaken by health sciences students studying science majoring in biomedical science (33%), nutrition (52%) and food science (3%). This class is predominantly female (83%) and comprises mostly domestic students (88%).

From the data collected, there are 61 students from one class (Class I, 61/251 = 24%) and 53 from the other (Class II, 53/107 = 50%). Based on descriptive analysis for each class separately, during which no major differences emerged, the two classes were combined for this report. Overall, 108 students had complete data (answered all eight items) and are included in the following analysis. The ASCIv2 results collected from students at a large US public research university, near the end of the semester are presented for comparison. Similar findings have been reported at another medium-sized public research university in the mid-western United States (Brandriet, Xu, Bretz, & Lewis, 2012). The data at the US university was collected from students who were enrolled in the first general chemistry class in the university curriculum. This class is taught with a tested and proven POGIL approach (Lewis & Lewis, 2005, 2008).

Data Analysis Methods

First, basic descriptive statistics for the eight items of ASCIv2 were obtained using SAS software version 9.2. The results are presented below in Table 1A along with the results from the US research university in Table 1B.

Next, evidence for reliability and validity was examined. For these analyses, the two data sets from Curtin were combined. For reliability, Cronbach's alpha estimates were calculated using SAS 9.2. Cronbach's alpha indicates the degree of internal consistency of the items within a particular scale. A high Cronbach's alpha suggests that the items scores are positively correlated with each other and with the total scale score as well. The larger the Cronbach's alphas for a set of items, the greater the assurance the items measure the same construct. The upper bound for Cronbach's alpha is 1.0, and values of at least 0.7 are generally desirable for research purposes (Murphy & Davidshofer, 2005).

For validity, evidence based on internal structure was obtained to support construct validity (American Educational Research Association, American Psychological Association, & National Council on Measurement in Education, 1999). Confirmatory factor analysis (CFA) was performed in Mplus 5.2 to estimate how well the designed two-factor correlated structure for the instrument fit the responses obtained with the sample (Muthen & Muthen, 2007). In addition to recommended cutoffs for model fit statistics, factor correlation and item loadings were used to evaluate the model fit (Bentler, 1990; Hu & Bentler, 1999).

Finally, once validity and reliability evidence supported score interpretation, students' attitude scores from Curtin were compared with scores from US students, using a standard effect size method (Cohen, 1988).

Results

Descriptive statistics:

The four negatively stated items (#1, 4, 5, and 7) were reversely coded for ease of interpretation. This means, the highest score of 7 on the original data was transformed to 1, and the lowest score of 1 was changed to 7, and so on. After recoding, the score interpretation for all eight items is in the same direction. A score higher than middle point 4 means positive attitude, i.e., students feel chemistry is intellectually accessible or emotionally satisfying. Descriptive statistics are shown in Table 1A for each item for both classes. The average scores range from 2.54 to 4.59, and standard deviations range from 1.16 to 1.54. No item was found to have skewness or kurtosis greater than .90, which suggests good normality of the item scores. The mean scores for most items are around the middle point of 4. The items with the highest mean scores are # 4, 5, 8, which means students in general feel chemistry is comfortable, satisfying and organized. Item 6 has the lowest mean score, which means students in both classes feel chemistry is challenging.

From comparison to US data in Table 1B, there is a similar trend for the 8 items. From the items with extreme scores (#6 & 8), both groups of students feel chemistry is organized, and is challenging. Because of the measurement error for the observed item scores, we will not compare the group difference based on item scores.

Table 1A Descriptive statistics for Curtin after recoding items 1, 4, 5 and 7

	Class I (n=58)				Class II (n=50)			
Item	**M**	**SD**	**Skew**	**Kurtosis**	**M**	**SD**	**Skew**	**Kurtosis**
1*Hard/ easy	3.78	1.27	-0.20	-0.13	3.04	1.32	0.25	-0.07
2 Complicated/ simple	3.67	1.28	0.02	-0.56	3.28	1.34	0.20	-0.10
3 Confusing/ clear	3.79	1.41	0.11	-0.37	3.68	1.48	-0.17	-0.75
4* Uncomfortable/ comfortable	4.59	1.34	-0.10	-0.05	3.90	1.40	-0.60	-0.05
5*Frustrating/ satisfying	4.34	1.55	-0.23	-0.49	4.00	1.76	-0.21	-0.90
6 Challenging/ unchallenging	3.29	1.17	0.21	0.29	2.54	1.16	0.51	0.27
7* Unpleasant/ pleasant	4.29	1.31	-0.28	0.29	3.88	1.55	-0.24	-0.18
8 Chaotic/ organized	4.57	1.43	-0.61	0.41	4.28	1.36	-0.64	0.19

Table 1B Descriptive statistics for the US university for comparison

Item	Mean	SD
1*Hard/ easy	2.81	1.28
2 Complicated/ simple	2.95	1.43
3 Confusing/ clear	3.36	1.40
4* Uncomfortable/ comfortable	3.64	1.36
5*Frustrating/ satisfying	3.24	1.70
6 Challenging/ unchallenging	**2.50**	1.50
7* Unpleasant/ pleasant	3.38	1.41
8 Chaotic/ organized	**4.26**	1.66

Note: Each item score ranges from 1 to 7, while 4 is the middle point. Bolded values indicate the range (largest and smallest values in a column.) A high value means students feel chemistry is intellectually accessible, emotionally satisfying. Adapted with permission from X. Xu and J. E. Lewis, Refinement of a Chemistry Attitude Measure for College Students, J. Chem. Educ. 2011, 88, 561–568, Table 2. Copyright 2011 by American Chemical Society and Division of Chemical Education, Inc.
**item score is reversed before averaging; items are shown reversed for ease of interpretation*

Validity results from CFA

CFA was performed to estimate goodness of fit for the designed 2-factor model. Items 1, 2, 3 and 6 were set to load on factor "*intellectual accessibility*" only; items 4, 5, 7 and 8 were set to load on factor "*emotional satisfaction*" only, and the two factors were allowed to correlate. The model was identified by fixing the first item on each factor at 1.

The estimation, illustrated in Table 2, of the 2-factor model fit for the Curtin data is: χ^2 (N = 108, df = 19, p < .001) = 53, CFI = .94, SRMR = .06. Since CFI was close to .95, and SRMR is less than .08, we can consider that the overall model does fit the data reasonably well. Factor correlation is .77. From Table 3, all eight items are loaded well on their intended scales. A factor loading represents the correlation between that item and the factor as a whole.

Table 2 CFA model fit for the 2-factor solution

Parameter	**Curtin** (N=108, 2011)	**US** (N=354)
χ^2	53	77
p-value	.00	.00
df	19	19
CFI	.94	.95
SRMR	.06	.04

2-Factor model fit for Curtin is similar with the results from a large US research university results. As shown in Table 2, the estimation of the 2-factor model fit with data obtained from a US university is: χ^2 (N = 354, df = 19, p < .001) = 77, CFI = .95, SRMR = .04. Results from US students are very comparable to the fit obtained with the Curtin data, which supports the tenability of the 2-factor structure for the ASCIv2 instrument.

Table 3 CFA item loadings for the 2-factor solution (N=108 for Curtin 2011)

Intended Factor	Item #	Item Loading
Intellectual Accessibility	Item 1	0.75
	Item 2	0.89
	Item 3	0.83
	Item 6	0.55
Emotional Satisfaction	Item 4	0.77
	Item 5	0.87
	Item 7	0.92
	Item 8	0.51

** all loadings are significantly different from 0 at the p=.05 level.*

Reliability

The internal consistencies were estimated for each subscale. Cronbach's alpha for Curtin students is .84 for the accessibility scale, which is above the satisfactory level of .7 and comparable to that obtained from a large US research university. Cronbach's alpha is .84 for the satisfaction scale, which is again above .7, and also comparable to a large US research university as shown in Table 4.

Table 4 Internal consistency reliability by Cronbach's alpha for ASCI-V2

Subscales of ASCI	Curtin	US
	2011(n=108)	(n=354)
Intellectual Accessibility (1,2,3,6)	.84	.82
Emotional Satisfaction (4,5,7,8)	.84	.79

Factor score comparison:

Based on the evidence of internal consistency reliability and factorial validity, it is safe to combine the items within each factor to calculate a factor score. Factor scores (for intellectual accessibility and for emotional satisfaction) and factor reliability by Cronbach's alpha are recalculated and shown in Table 5. The intellectual accessibility factor is the average score of three items 1, 2, 3, and 6. The emotional satisfaction factor is the average of four items of 4, 5, 7, and 8. All negative items are reverse coded before summing, and the possible factor score may range from 1 to 7, with the 4 at the middle point. Higher values mean greater intellectual accessibility and greater emotional satisfaction.

Although students are from two countries, we cannot make generalizations for comparing attitude levels between the two countries because the sample is not representative of the population of each country. Likewise, there are also differences in the data collection, where US students are in the same course and combined, but not so in Australia. However, we can have an impression of the overall attitude status for students in each chemistry program in this study. To do this we use effect size, which has the advantage of allowing comparison across samples, designs, and analyses as re-emphasized by Wilkinson *et al*. (1999).

Table 5 Factor scores for each subscale for US and Curtin students

School	Variable	Mean	SD	Skewness	Kurtosis	*P* value for t-Test	Effect size[1]
Curtin I	Accessibility	3.63	0.98	-0.49	0.79	-	-
(N=58)	Satisfaction	4.45	1.10	-0.21	-0.17	-	-
Curtin II	Accessibility	3.14	1.16	-0.24	-0.55	P = .02	.47
(N=50)	Satisfaction	4.02	1.31	-0.51	-0.10	P =.07	.36
US	Accessibility	2.91	1.13	0.32	-0.25	P < .001[2]	.65
(N=354)	Satisfaction	3.63	1.2	-0.03	-0.08	P < .001[2]	.69

[1] *All effect size comparisons are made with respect to Curtin I.*

[2] *Statistically significant at the adjusted alpha level of .05/4=.013*

Cohen's *d* effect size can be used to quantify the difference in the attitude between US students and Curtin students and are provided in Table 5 (Cohen, 1988). Values for Cohen's *d* of 0.2 to 0.3 are generally considered a "small" effect, around 0.5 a "medium" effect and 0.8 or above, a "large" effect. A medium effect size reflects a difference that would be noticeable to a careful observer. For the two classes at Curtin, Class I students feel chemistry is more accessible (by .46 standard deviation units, a medium effect size) and slightly more emotionally satisfying (by .36 standard deviation units, a small effect size) than Class II students do. The more dramatic differences emerge when the Curtin students from Class I are compared to the students from the US. In this case, all of the effect sizes are above .5, signaling observable differences between attitudes in the US and at Curtin. The t-Test in Table 3 indicates that the group differences is statistically significant between Curtin class I and the US students.

Conclusions

The first important issue, whether the instrument "works" in Australia from a basic psychometric perspective, seems to have been resolved positively. From the data analysis, ASCIv2 functions in a similar way for Curtin University students as with US students. In other words, the 2-factor model produced a decent fit with the combined Curtin data, with each of the eight items loaded on its appropriate subscale. The internal consistency reliability as measured by Cronbach's alpha was above .8 for both scales, which indicates the instrument meets acceptable standards for research (Murphy & Davidshofer, 2005).

The second question of interest, whether the student attitudes measured at Curtin are more or less positive than those currently in the literature, also had a definitive answer. Compared with US students from a large southeastern public research university at the 11th week of a semester of the first college chemistry class in the curriculum, Curtin students from October 2011 in a first year general (Class I) and organic and biological chemistry (Class II) unit of study think that chemistry is more accessible and more emotionally satisfying (by .51 standard deviation units), both medium effect sizes (Cohen, 1988). A medium effect size reflects a difference that would be noticeable to a careful observer. For the two classes at Curtin, class I students feel chemistry is more accessible (by .47 standard deviation units, medium effect size) and more emotionally satisfying (by .36 standard deviation units) than class I students do.

Our desire to determine whether ASCIv2 could be useful in the Australian context, where increased student engagement is a key aspect of curriculum reform efforts, seems to have borne fruit. The instrument scores obtained from trialing the instrument with two classes of Curtin University students met some commonly accepted psychometric standards, and we believe it is likely that other institutions in Australia would also find the instrument easy to use and to interpret. What remains is to explain how the nature of the two Curtin classes may give rise to these observable differences to those in the US.

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Understanding rate of acid reactions: Comparison between pre-service teachers and Grade 10 students

Kim Chwee Daniel Tan,[1]* Mauro Mocerino,[2] David F. Treagust[3] and A.L. Chandrasegaran[3]

[1]National Institute of Education, Nanyang Technological University, 1 Nanyang Walk, Singapore 637616, Republic of Singapore, [2]Department of Chemistry, Curtin University, GPO Box U1987, Perth, Western Australia 6845, Australia, [3]Science and Mathematics Education Centre, Curtin University, GPO Box U1987. Perth, Western Australia 6845, Australia. daniel.tan@nie.edu.sg

Abstract

A two-tier multiple choice diagnostic instrument on the stoichiometry and rate of acid reactions was administered to 611 Grade 10 students and 171 pre-service teachers. The results showed that the Grade 10 students and pre-service teachers held alternative conceptions related to the properties of different acids affecting their rates of reaction, and the particles in the resulting mixtures at the end of the reactions. The study stresses the importance of identifying and clarifying the pre-service teachers' understanding of the concepts that they will teach as this may have consequences on their future students' learning of chemistry.

Introduction

Chemistry is a difficult subject for students to learn, even up to the tertiary levels (Nieswandt, 2001; Taber, 2000), because explanations of chemical phenomena not only involve abstract concepts and models, they can also be communicated and perceived in three different but inter-related ways such as experiences, models and visualizations (Talanquer, 2011). For example, when excess dilute hydrochloric acid is added to a piece of magnesium ribbon, students can see bubbles forming on the metal, and the metal becomes smaller and smaller until it disappears. If sensors are used to monitor the reaction, they can see changes in pH, temperature and/or pressure in digital and/or graphical forms, or if a gas syringe is used to collect the hydrogen gas, changes in volume can be observed. These are the students' experiences of the chemical phenomena. At the secondary level, the teacher can provide explanations of the reaction using models of varying sophistication. For example, the teacher can simply state that a metal reacts with an acid to produce a salt and hydrogen, or also point out that a redox reaction has occurred where the metal donates electrons to the hydrogen ions which come into contact with it to form hydrogen gas. In secondary chemistry (Grades 9 and 10) in Singapore, the simpler term, 'hydrogen ions', is used instead of 'hydroxonium ions'. Deeper understanding of acid reactions will require knowledge of acid-base models and concepts such as acid strength, neutralization, pH, dissociation and chemical equilibrium, and research has shown that students have difficulty understanding these concepts (Baddock & Bucat, 2008; Carr, 1984; Lin & Chiu, 2007; McClary & Talanquer, 2011; Nakhleh & Krajcik, 1994; Ross & Munby, 1991; Schmidt, 1997; Sheppard, 2006; Wilson, 1998). As the concepts involved in acid reactions are numerous and intertwined, if students have problems understanding one concept, they will have difficulty learning other related concepts as well (McClary & Talanquer, 2011; McDermott, 1988; Ross & Munby, 1991; Sheppard, 2006).

To represent the experience and the explanations of magnesium reacting with hydrochloric acid, the teacher could use chemical symbols and equations such as:

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

$$Mg(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$$

The teacher could also show the students animations of the particles interacting during the reaction to help them understand the phenomenon and the models used to explain it. Thus, students have to coordinate the information from their sensory experiences of the phenomena and the explanations, as well as the models and visualisations provided by the teacher or textbook, to form a coherent understanding of the reaction of magnesium and hydrochloric acid.

If the students are studying the rate of acid reactions, they need to be able to interpret or compare graphs depicting amount of product or reactant over time, a common task in secondary school kinetics in Singapore. In addition to understanding the conventions of graphical representations, students also need to understand the chemistry involved, for example, the characteristics of the reactants, reactions and products, the stoichiometry involved and the factors affecting the rates of reactions as these would determine the amounts of reactants used up or products formed, and how fast they are formed (Tan, Treagust, Chandrasegaran, & Mocerino, 2010). For example, if students are comparing the reactions of sulfuric, hydrochloric and ethanoic acids with similar masses of powdered magnesium at the same temperature, they need to bear in mind which reactant is the limiting reagent as this will impact on the amount of hydrogen gas and salt formed, as well as the concentration and dissociation of the acids as these will impact on the concentration of hydrogen ions reacting with the metal, and hence the rate of reaction. Understanding the graphs involved may be challenging as studies have shown that students have difficulty with the concepts involved in chemical kinetics (Cakmakci, Leach, & Donnelly, 2006; van Driel, 2002), stoichiometry (Chandrasegaran, Treagust, Waldrip, & Chandrasegaran, 2009; Gauchon & Meheut, 2007) and have problems interpreting graphs (Leinhardt, Zaslavsky, & Stein, 1990; Testa, Monroy, & Sassi, 2002).

Teachers, too, may have similar alternative conceptions and difficulties as their students (Abell, 2007), for example, in the areas of chemical equilibrium (Quilez-Pardo & Solaz-Portoles, 1995) and chemical kinetics (Justi, 2002). It is important to help teachers to identify their own alternative conceptions and difficulties, and address them because their own conceptions may impact on how they teach their students (de Jong, Veal, & van Driel, 2002; Crawford, 2007) and give rise to poor learning of concepts by their students.

Purpose

The study sought to compare pre-service teachers' and Grade 10 students' understanding of the concepts involved in the stoichiometry and rate of acid reactions and to highlight the significance of the nature of the alternative conceptions. A two-tier multiple choice diagnostic instrument, the Acid Reactions Diagnostic Instrument, was used in the study, and it was developed from an open-ended version used in an earlier study (Tan et al., 2010).

Instrument

The Acid Reactions Diagnostic Instrument (ARDI) (see Appendix), was developed through several stages (Treagust, 1995) which included the clarification of the curricular content knowledge, interviews and open-ended versions of the instrument (Tan et al., 2010) before the version used in this study was finalized. It consists of six single-tier and eight two-tier multiple-choice items. Two-tier multiple-choice items require the participants to select two options, the answer and the reason for the answer. Only if both options are correctly selected is the two-tier multiple-choice question considered correctly answered (Peterson, Treagust, & Garnett, 1989). There are four reaction scenarios, each consisting of three questions, in the instrument. The first item in each scenario requires the participants to select a graph which best describes the two reactions involved. The following two items require students to explain the amount of gases formed and the rate of the two reactions in the scenario. The last two items (items 13 and 14) were designed to clarify the participants' understanding of excess and limiting reagents as it was difficult to decide if the participants gave wrong answers in the earlier items due to their misreading of the questions or if they actually had difficulties with the concepts of excess and limiting reagents. Six chemistry teachers reviewed the items in the ARDI and agreed that the content assessed by the ARDI is in line with the national secondary chemistry syllabus and taught in schools.

Method and procedures

The study involved 611 Grade 10 students from six Singapore schools in 2010 and 171 graduate pre-service teachers from a teacher education institution in Singapore over the period 2010 and 2011. It was part of a larger collaborative research project focusing on the development of diagnostic instruments to identify student conceptual difficulties in chemistry and received human ethics research approval (SMEC-47-09).

Convenience sampling was used in the study. Six schools in Singapore which were approached by the first author agreed to participate in the study. The Grade 10 students in the schools were chosen by the schools and the ARDI was administered to the students after they were taught the topics of Bonding, Acids, Bases and Salts, Stoichiometry and Reaction Kinetics, all of which were required in the secondary chemistry syllabus. Only the overall analysis of the results of the students in a particular school was reported back to the school with an offer of discussions with teachers on students' difficulties and how to address these; none of the offers to the six schools was taken up. The graduate pre-service teachers in the sample were from a teacher education institution in Singapore. They answered the ARDI as part of a series of lessons designed to highlight difficult concepts in secondary chemistry. It was one of the three diagnostic instruments used in the lessons, the other two being the Qualitative Analysis Diagnostic Instrument (Tan, Goh, Chia, & Treagust, 2002) and Taber's (1997) instrument on ionic bonding. The pre-service teachers were informed in advance to read up the relevant Grade 10 chemistry material before attempting the diagnostic instruments and had also seen demonstrations of the reaction of magnesium with similar concentrations of sulfuric acid, hydrochloric acid and ethanoic acid in a session on the instructional use of demonstrations and the Predict-Observe-Explain strategy. The pre-service teachers' results were used, in subsequent sessions, to compare with secondary students' results reported in the literature or collected by the first author to facilitate discussions on the prevalence and 'longevity' of alternative conceptions (Taber & Tan, 2011), and how to address them when teaching in school.

Graduate pre-service teachers aspiring to teach in secondary schools are assigned two teaching subjects. Ninety-five pre-service teachers were assigned secondary chemistry as their first teaching subject (CS1) and these teachers would have at least undergraduate degrees in science (majoring in chemistry), material science, material engineering or chemical engineering. The remaining 76 pre-service teachers were assigned secondary chemistry as their second teaching subject (CS2). They would have studied at least up to Grade 12 chemistry; many of them have science degrees but majored in mathematics, life sciences or physics, while the rest are usually engineering graduates. The content of the chemistry pedagogy courses and the way the courses were conducted were similar for both groups of pre-service teachers as both groups could be assigned to teach secondary chemistry in school. The main difference between the two groups is that the CS1 pre-service teachers can be assigned to teach Grades 11 and 12 chemistry as well.

Results

The answer sheets were scanned using an optical mark reader, and the results were analysed using IBM SPSS Statistics version 19 (SPSS Inc, 2010). Questions 1, 4, 7, 10, 13 and 14 are single-tier multiple choice questions, and contain 5 to 8 options. The reason for the use of options (A-E) and (1-5) is that the answer sheet was designed for two-tier tests in which respondents chose an answer (A-E) and a reason for the answer (1-5). Thus, to accommodate up to 10 options, (A-E) and (1-5) of each row of answers had to be utilised. There should not be any errors in recording responses as options (A-E) and (1-5) have corresponding circles to be shaded on the answer sheet. There were respondents who provided 'two responses' for the single-tier questions. However, these were not taken into account when the results of these questions were analysed.

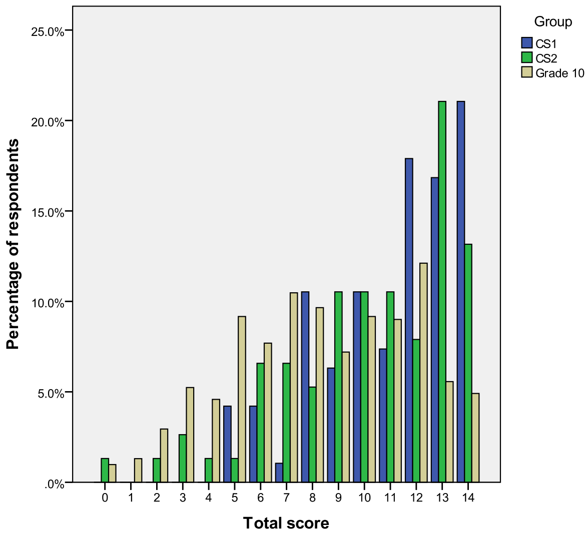


Figure 1. Distribution of total scores of the two groups of pre-service teachers and the Grade 10 students

Some test statistics are given in Table 1 and the distribution of the total scores is illustrated in Figure 1. The pre-service teachers did reasonably well, the mean total score of the CS1 and CS2 groups being 11.09 and 10.18 (out of a maximum of 14), respectively, compared to the mean total score of 8.26 of the Grade 10 students. However, it is rather disconcerting that 9.5% and 21.1% of the pre-service teachers in the CS1 and CS2 groups, respectively, scored 7 marks or less in the test (Grade 10: 42.4%). A one-way analysis of variance (ANOVA) showed that there was a statistically significant difference between mean total scores of the three groups ($p<0.001$). A post hoc pairwise multiple comparisons analysis (Dunnett's T3) was conducted and it showed that there was no statistically significant difference between the mean total scores of the two groups of pre-service teachers ($p=0.144$). As expected, both groups of pre-service teachers' mean total scores were statistically significantly different compared to that of the Grade 10 students ($p<0.001$ for both comparisons). However, any comparison needs to be taken with caution because of the different numbers of Grade 10 students ($n=611$) and pre-service teachers ($n[CS1]=95$, $n[CS2]=76$) involved. The pre-service teachers' and Grade 10 students' correct responses to the four reaction scenarios are given in Table 2. As expected, the percentages of the pre-service teachers and Grade 10 students who choose the correct graph in each reaction scenario (CS1, 64–87%; CS2, 62–76%; Grade 10, 52–80%) are generally higher than those who chose the correct graphs and explanations for the volumes of gas formed and the rates of the reaction involved (CS1, 59–85%; CS2, 50–72%; Grade 10, 40–69%). Cronbach alpha values for the instrument administrated to the three groups range between 0.73 to 0.82 indicating acceptable to good internal consistency.

Table 1 Test statistics for the administration of the ARDI to pre-service teachers and Grade 10 students

	CS1	CS2	Grade 10
No. of cases	95	76	611
Cronbach alpha reliability	0.732	0.816	0.820
Mean (Standard deviation)	11.09 (2.62)	10.18 (3.28)	8.26 (3.45)
Median / Mode	12.00 / 14	11.00 / 13	8.00 / 12
Minimum / Maximum	5 / 14	0 / 14	0 / 14
Number (Percentage) of respondents whose total scores are 7 and below	9 (9.5)	16 (21.1)	259 (42.4)

Notes: CS1 represents pre-service teachers with chemistry as their first teaching subject. CS2 represents pre-service teachers with chemistry as their second teaching subject

Alternative conceptions

Table 3 summarises the alternative conceptions of the two groups of pre-service teachers and Grade 10 students. Alternative conceptions are considered significant if they exist in at least 10% of the sample (Tan et al., 2002). In general, the effect of the same concentration of different acids on the initial rate of reactions posed difficulties to both groups of pre-service teachers and Grade 10 students. As mentioned earlier, items 13 and 14 were included in the instrument to clarify the respondents' understanding of excess and limiting reagents. However, in addition to performing this task, the two items also revealed students' ideas of the existence of the various particles in solution.

The initial rates of reaction of different acids of the same concentration are equal

In items 1, 7 and 10, more than 10% of the respondents in the three groups chose graphs which indicated that the correct volumes of gas liberated but incorrect initial rates of reaction; they thought that initial rate of reaction of the same concentration of different acids were the same (see Figure 2). The hydrochloric/sulfuric acid pair in item 1 (Option 2: CS1, 27%; CS2, 28%; Grade 10, 20%) and item 10 (Option B: CS1, 19%; CS2, 25%; Grade 10, 25%) seemed to pose more difficulty than the hydrochloric/ethanoic acid pair in item 7 (Option 2: CS1, 12%; CS2, 18%; Grade 10, 19%). Cross-tabulation (see Table 4) showed that about half of the respondents were consistent in their choices in item 1 and item 10 (CS1, 12%; CS2, 17%; Grade 10, 9%) but fewer respondents were consistent in items 1 and 7 (CS1, 3%; CS2, 8%; Grade 10, 10%) and in all three items (CS1, 3%; CS2, 5%; Grade 10, 5%).

Table 2 Test statistics for the administration of the ARDI to pre-service teachers and Grade 10 students

Reaction Scenarios	Reaction kinetics	CS1 (n = 95)	CS2 (n = 76)	Grade 10 (n = 612)
1	Excess 1M-HCl and 1M- H_2SO_4 with $CuCO_3$:			
	Correct response to Q1	61 (64)	48 (63)	319 (52)
	Correct responses to Q1, Q2 (1st tier) & Q3 (1st tier)	57 (60)	48 (63)	305 (50)
	Correct responses to Q1, Q2 (both tiers) & Q3 (both tiers)	56 (59)	48 (63)	300 (49)
2	Excess 1M-HCl and 0.5M-HCl with $CaCO_3$:			
	Correct response to Q4	83 (87)	56 (74)	492 (80)
	Correct responses to Q4, Q5 (1st tier) & Q6 (1st tier)	82 (86)	56 (74)	465 (76)
	Correct responses to Q4, Q5 (both tiers) & Q6 (both tiers)	81 (85)	55 (72)	424 (69)
3	Excess 1M-HCl and 1M-CH_3COOH with $CaCO_3$:			
	Correct response to Q7	72 (76)	58 (76)	319 (52)
	Correct responses to Q7, Q8 (1st tier) & Q9 (1st tier)	69 (73)	57 (75)	294 (48)
	Correct responses to Q7, Q8 (both tiers) & Q9 (both tiers)	61 (64)	42 (55)	247 (40)
4	Excess magnesium with 1M-HCl and 1M- H_2SO_4:			
	Correct response to Q10	69 (73)	47 (62)	396 (66)
	Correct responses to Q10, Q11 (1st tier) & Q12 (1st tier)	64 (67)	41 (54)	372 (62)
	Correct responses to Q10, Q11 (both tiers) & Q12 (both tiers)	59 (62)	38 (50)	368 (61)

Table 3 Significant alternative conceptions of the pre-service teachers and the Grade 10 students

Alternative conception	Choice combination	Percentage of respondents who held the alternative conception		
		CS1 (n=95)	CS2 (n=76)	Grade 10 (n=611)
The initial rates of reactions of different acids of the same concentration are equal (graph with the correct volumes of gas liberated are correct)	Q1 (2) Q7 (2) Q10 (B)	27 12 19	28 18 25	20 19 25
The two initial rates of reaction are equal because both acids have the same concentration (text)	Q3 (B1) Q9 (B2) Q12 (B2)	12 ~ 14	14 ~ 17	23 11 27
The two initial rates of reaction are equal because both acids are in excess	Q3 (B2)	10	~	~
The two initial rates of reaction are equal because the strength of the acid does not affect its rate of reaction	Q9 (B3)	~	~	14
The two initial rates of reaction are equal because both the acids are strong acids	Q12 (B1)	~	12	~
Ignored excess/limiting reagents	Q5 (C4) Q11 (B2)	~ ~	~ ~	11 11
Ionic 'molecule' in solution	Q13 (B) Q14 (E)	17 16	24 26	52 50
Electrically unbalanced solution	Q14 (3)	15	14	10

Note: ~ represents a figure which is less than 10%

In items 3, 9 and 12, the respondents had to explain the rates of reaction represented by the graphs in items 1, 7 and 10. It could be seen again in Table 3 that the percentage of students explaining that the rates of reactions were the same because the acids were of the same concentration was higher in items 3 (Option B1: CS1, 12%; CS2, 14%; Grade 10, 23%) and 12 (Option B2: CS1, 14%; CS2, 17%; Grade 10, 27%) which involved the hydrochloric/sulfuric acid pair than item 9 which involved the hydrochloric/ethanoic acid pair (Option B2: CS1, <10%; CS2, <10%; Grade 10, 11%). More than half of the pre-service teachers and about half the Grade 10 students were consistent in their 'same concentration same rate of reaction' reasoning (see Table 4) in items 3 and 12 (CS1, 9%; CS2, 12%; Grade 10, 13%); however, consistency in this reasoning across items 3, 9 and 12 is low (CS1, 0%; CS2, 1%; Grade 10, 6%).

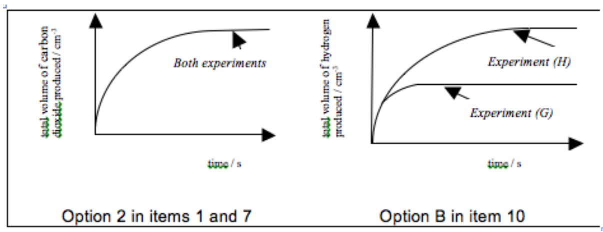


Figure 2 Options indicating 'same concentration same rate of reaction' alternative conception

Table 4 Consistency of pre-service teachers' and Grade 10 students' alternative conceptions

Alternative conception	Percentage of respondents who held the alternative conception		
	CS1 (n=95)	CS2 (n=76)	Grade 10 (n=611)
The initial rates of reactions of different acids of the same concentration are equal. Volumes of gas liberated are correct			
Graph			
Q1 (2) & Q7 (2)	3	8	10
Q1 (2) & Q10 (B)	12	17	9
Q1 (2), Q7 (2) & Q10 (B)	3	5	5
Text			
Q3 (B1) & Q12 (B2)	9	12	13
Q3 (B1), Q9 (B2) & Q12 (B2)	0	1	6
Graph and text			
Q1 (2) & Q3 (B1)	7	12	16
Q7 (2) & Q9 (B2)	3	7	7
Q10 (B) & Q12 (B2)	11	14	15
Ignored excess/limiting reagents			
Q5 (C4) & Q11 (B2)	0	1	2
Ionic 'molecule' in solution			
Q13 (B) & Q14 (E)	16	21	45

The next step taken was to cross-tabulate respondents' answers within the same reaction scenarios to determine if the 'same concentration same rate of reaction' reasoning was consistent across the respondents' graphical and text description choices. The results show that the consistency in the respondents' choices is higher again for items 1 and 3, and 10 and 12 involving the hydrochloric/sulfuric acid pair than for items 7 and 9 involving the hydrochloric/ethanoic acid pair (see Table 4). This is expected as, in general, a higher proportion of respondents exhibited the 'same concentration same rate of reaction' reasoning in the reaction scenarios involving the hydrochloric/sulfuric acid pair.

Other alternative conceptions related to the initial rates of reaction

Other incidences of significant alternative conceptions related to the initial rates of reaction are few and involved only one of the three groups of respondents (see Table 3). For example, in item 3 (B2), 10% of the CS1 pre-service teachers indicated that the initial rates of reaction of powdered copper(II) carbonate with hydrochloric acid and sulfuric acid, respectively, are the same because both acids were in excess, while 12% of the CS2 pre-service teachers pointed out in item 12 (B1) that the initial rates of reaction of the same two acids with powdered magnesium were the same because the acids were strong acids. In item 9 (B3), 14% of the Grade 10 students indicated that the initial rates of reaction of powdered marble with hydrochloric and ethanoic acids were the same because the strength of the acids did not affect their rates of reaction.

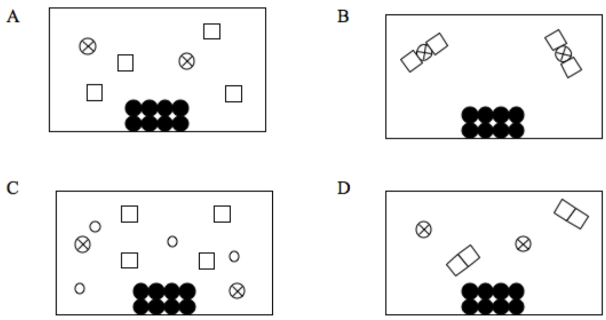
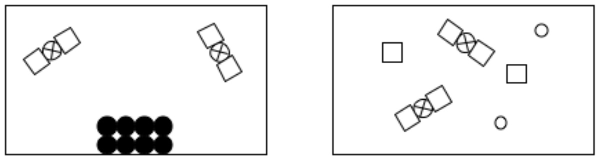


Figure 3 Options indicating excess metal in reaction mixture in item 14

Ignoring excess/limiting reagents

A number of Grade 10 students (11%) seemed to ignore that the 0.5 mol dm^{-3} and 1 mol dm^{-3} hydrochloric acids were in excess, and chose option C4 in item 5 stating that the reaction of powdered marble with 1 mol dm^{-3} hydrochloric acid will liberate more carbon dioxide because it contains more hydrogen ions (see Table 3). Cross-tabulation with item 14 showed that only 12 students (2%) chose options A, B, C or D in item 14 which indicated that the metal was in excess (see Figure 3) when it was stated in the item that the acid was in excess. Similarly, another 11% of the Grade 10 students ignored the fact that the acids were the limiting reagent in item 11 (B2) but cross-tabulation with item 13 showed that only 11 students (2%) chose options E, 1, 2, 3, 4 or 5 indicating that the acid was in excess when it was stated that the metal was in excess. The consistency of the Grade 10 students' choices is only 2% in item 5 (C4) and item 11 (B2). The pre-service teachers did not have any significant problem with excess/limiting reagents.



Option B in item 13   Option E in item 14

Figure 4. Options indicating 'ionic molecules' in solution

Ionic molecules in solution and electrically unbalanced solution

The use of items 13 and 14 to determine the respondents' understanding of excess and limiting reagents in terms of the particles present in solution when the reactions were completed indicated that the respondents had minor problems with excess and limiting reagents, but revealed the existence of 'ionic molecules in solution' and 'electrically unbalanced solution' alternative conceptions. A significant number of respondents chose option B in item 13 (CS1, 17%; CS2, 24%; Grade 10, 52%) and option E in item 14 (CS1, 16%; CS2, 26%; Grade 10, 50%) which showed the ionic salt, MgY_2, existing as a molecule (see Figure 4), and this thinking was consistent across the two items (CS1, 16%; CS2, 21%; Grade 10, 45%). Item 14 (3) also indicated that a number of respondents (CS1, 15%; CS2, 14%; Grade 10, 10%) ignored the fact that the charges of the oppositely charged particles were unbalanced; insufficient Y^- ions were present to balance the positive Mg^{2+} and H^+ ions in the diagram (see Figure 5).

Discussion

From Table 2, it can be seen that a large majority of pre-service teachers and Grade 10 students who chose the correct graphical representations of the reactions in each reaction scenario chose the correct textual descriptions of the graphs in first tier options of the second and third items in the same reaction scenario (CS1, 93-99%; CS2, 87-100%; Grade 10, 92–96%) as well as provided correct explanations for the volumes of gas formed and the rates of reaction (first and second tier options in the second and third items in the same reaction scenario) (CS1, 85-98%; CS2, 72-100%; Grade 10, 77-94%). This indicates the importance of exposing students to both graphical as well as textual/verbal descriptions when teaching rates of reaction as they serve complementary roles in helping students to construct deeper understanding of the concepts involved (Ainsworth, 1999); the graphs can illustrate textual/verbal descriptions of reaction changes due to changes in the variables involved or of the comparison of two different reactions, facilitating understanding of the textual/verbal descriptions. Reaction scenario 2 which involved different concentrations of only one acid seemed to cause lesser problems than the other reaction scenarios which involved two different acids as more participants chose the correct graph and explanations for this scenario compared to the other three reaction scenarios. This is expected as the complexity of determining how the characteristics of different acids affect the rate of reaction and volume of gas formed does not come into play in this case, making comparisons easier.

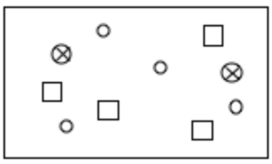


Figure 5. Option indicating an electrically unbalanced solution in item 14

Similar to the earlier study (Tan et al., 2010), a significant number of respondents chose graphs which indicate equal initial rate of reactions for the hydrochloric/sulfuric acid pair in items 1 (20-28%) and 10 (19-25%) and the hydrochloric/ethanoic acid pair in item 7 (12-19%) (see Figure 2). The main reason given by the respondents was that both acids had the same concentration (Q3 (B1): 12-23%; Q12 (B2) 14-27%; Q9 (B2): 3-11%). In Grade 9 and 10 chemistry, students learn that concentration is one of the factors that affect the rate of reaction and since the concentration of the different acids are the same in reaction scenarios 1, 3 and 4, it is easy to understand why Grade 10 students chose the incorrect 'same concentration same rate of reaction' option. They might have taken what was taught at face value and did not understand that the characteristics of the reactants, reaction itself, products formed and stoichiometry involved needed to be considered in greater detail. For example, marble chips will react with hydrochloric acid to liberate carbon dioxide until the limiting reagent is used up. However, the reaction of marble chips and sulfuric acid (not included in the ARDI) will slow down and stop producing carbon dioxide soon after the reaction starts due to the formation of a coating of sparingly soluble calcium sulfate on the surface of the marble chips, preventing further reaction between the acid and the calcium carbonate. Sulfuric acid will react with a metal or carbonate faster than hydrochloric acid of the same volume and concentration provided a *soluble sulfate* is formed. Being a diprotic acid, and although its second ionisation is low, the hydrogensulfate ions will dissociate further to generate more hydrogen ions as they are used up, unlike hydrochloric acid where the hydrogen ions cannot be replenished, causing a drop in the concentration of hydrogen ions and slowing down its rate of reaction. Thus, graph 1 in item 1 and graph D in item 10 are the best options.

$$H_2SO_4\,(aq) + H_2O\,(l) \rightarrow H_3O^+\,(aq) + HSO_4^-\,(aq),\ pK_a = -3.0$$

$$HSO_4^-\,(aq) + H_2O\,(l) \rightarrow H_3O^+\,(aq) + SO_4^{2-}\,(aq),\ pK_a = 1.9$$

It is rather surprising that the pre-service teachers also exhibited the 'same concentration same rate of reaction' alternative conception even after learning chemistry at more advanced levels, albeit at a lower percentage compared to the Grade 10 students, and quite a number exhibited this thinking consistently in items involving the hydrochloric/sulfuric acid pair in reaction scenarios 1 and 4 (see Tables 3 and 4). These pre-service teachers still focused on the concentration of the acids rather than the concentration of the hydrogen ions present in the acids (Tan et al., 2010), highlighting the insidious nature (Taber & Tan, 2011) of this alternative conception. Thus, there is a need to emphasise the ionic equations and the stoichiometry of the reaction when discussing the reactions of acids to focus attention that the reacting species is the hydrogen ion rather than the acid per se. Other minor incorrect reasons that the respondents offered to explain why the hydrochloric/sulfuric acid pair and the hydrochloric/ethanoic acid pair had the same initial rate of reaction included (i) both acids were in excess (Q3 (B2): CS1, 10%), (ii) both acids were strong acids (Q12 (B1), CS2, 12%) and (iii) the strength of an acid did not affect its rate of reaction (Q9 (B3), Grade 10, 14%). Merely watching the reactions of the same concentration and volume of the three acids with magnesium apparently did not make much of an impression; the demonstrations or practical activities need to be supported with illustrations of the particles and their interactions at the sub-microscopic level to represent the reaction in multiple and complementary ways to help students (and pre-service teachers) construct deeper understanding of the process (Ainsworth, 1999). Computer animations or relevant diagrams can be used to show what excess reagent and strength of acids mean at the sub-microscopic level and how these affect reactions. For example, even if an acid is in excess, it is still the number of hydrogen ions in the immediate vicinity of the metal and colliding with metal that is responsible for the reaction rate, and this number of hydrogen ions is determined by the concentration and dissociation of the acid rather than the excess hydrogen ions which are spread throughout the mixture.

The respondents, in general, had little difficulty with the concepts of excess and limiting reagents per se, as indicated by their answers in items 14 and 13, even though they made incorrect choices in items 5 and 11, respectively. However, items 13 and 14 established that the respondents had problems with the representation of '$MgY_2(aq)$', with about 17% of the CS1 group, 25% of the CS2 group and 51% of the Grade 10 students incorrectly believing that MgY_2 exists as 'ionic molecules' (Taber, 1997; Tan & Treagust, 1999) in solution, and the consistency of their alternative conception ranged from 16% (CS1) to 45% (Grade 10). Devetak and Glazar (2010) also found that students in their study had problems representing soluble ionic substances in solution, drawing aqueous potassium bromide as ion-pair molecules. Taber (1997) and Tan and Treagust (1999) argue that the teaching of ionic bonding at the secondary level, focussing on the transfer of electrons to form discrete units of the ionic compound, encourages students to adopt this molecular framework (Taber, 1997) and this is another tenacious alternative conception, defying the impact of additional years of chemical education. Item 14 also revealed the 'electrically unbalanced solution' choice which a number of respondents (10-15%) made. These respondents might have focussed only on the hydrogen ions in the depiction of excess acid, forgetting that an equal number of counter-ions (Y^-) would have to be present as well. The learning of the ions present in solution (and in the molten state) can be facilitated, again, by computer animations or the use of relevant diagrams to give students a picture of how solutions of ionic compounds (and molten ionic compounds) would look like; hopefully, this would minimise students and pre-service teachers persisting with the molecular framework.

Conclusion

This study indicates that the pre-service teachers and Grade 10 students did not have difficulty with the concepts of excess and limiting reagents per se although a number of Grade 10 students seemed to ignore the excess and limiting reagents when determining the amounts of products formed in reactions. However, many pre-service teachers and Grade 10 students had alternative conceptions related to rates of reaction of different acids such as the initial rate of reaction of the same concentration of acids of different proticity or strengths are equal. They also had problems describing how the various substances exist in resulting mixtures at the end of the reaction, for example, they indicated that 'ionic molecules' exist in solution or chose options which show electrically unbalanced solutions. The most likely cause of these difficulties is the lack of understanding of the sub-microscopic representations of the properties and reactions of acids (Tan et al., 2010). Thus, there is a pressing need for illustrations of the entities and process at the sub-microscopic level to be included in chemistry lessons to foster complementary learning and deeper understanding (Ainsworth, 1999). The study also highlights the need to help pre-service teachers to identify tenacious alternative conceptions that they may have and clarify their understanding of the chemistry concepts that they will be teaching as what they think about these concepts may affect their classroom teaching and the learning of their future students.

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APPENDIX

ACID REACTIONS DIAGNOSTIC INSTRUMENT

Instructions

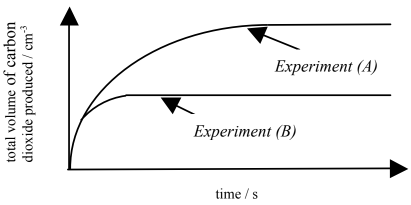
1. This paper consists of 14 questions.
2. In the first part of each question, shade one of the options to indicate what you consider to be the most appropriate answer, i.e., A, B, C, D or E.
3. In the second part of each question, where required, shade one of the options to indicate what you consider to be the most appropriate reason/justification, i.e., 1, 2, 3, 4 or 5.
4. Note that questions 1, 4, 7, 10, 13 and 14 do not require reasons but options 1 to 5 are used as answer options as well.
5. If you feel that all options and/or reasons given are inappropriate, indicate the question number and write down what you think the correct answer and/or reason should be behind the answer sheet.

For Questions 1 to 3 refer to Laboratory Activity 1

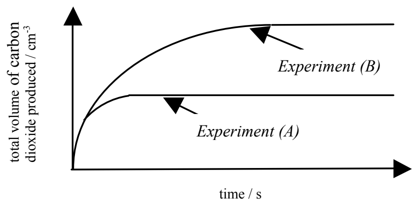
Laboratory Activity 1

1. In Experiment (A), **excess** 1 mol dm^{-3} hydrochloric acid (HCl) was added to a flask containing some powdered copper(II) carbonate.
   In Experiment (B), the same volume of **excess** 1 mol dm^{-3} sulfuric acid (H_2SO_4) was added to a flask containing the same amount of powdered copper(II) carbonate as in the first experiment.
   Which of the graphs indicates the volume of carbon dioxide produced as the reactions progressed?
   Note: Choose one option from A to 3.

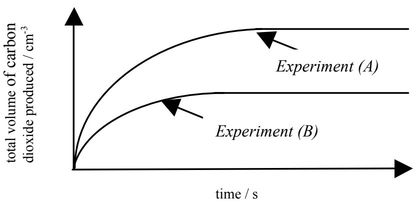
A



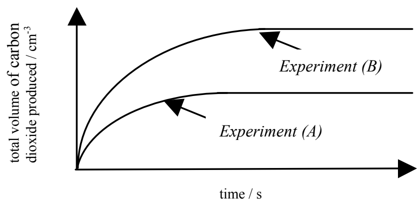
B



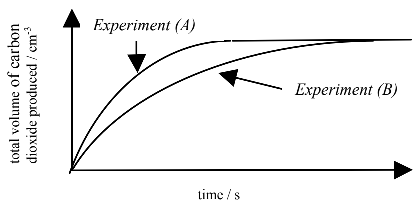
C



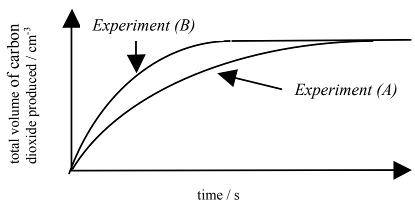
D



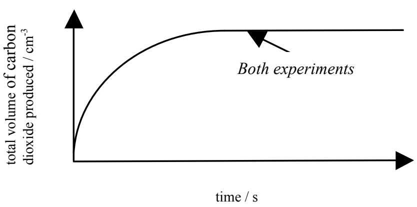
E



1



2



3. If you do not agree with any of the options given, shade 3, write down the question number 1 at the back of your answer sheet and draw your answer.

2. The total volume of gas produced by the reaction involving hydrochloric acid (HCl) is ________ the total volume of gas produced by the reaction involving sulfuric acid (H_2SO_4).

   A. less than
   B. equal to
   C. greater than

   Reason/Justification

   [1] Hydrochloric acid (HCl) is a stronger acid than sulfuric acid (H_2SO_4).
   [2] Sulfuric acid (H_2SO_4) is a stronger acid than hydrochloric acid (HCl).
   [3] One mole of copper(II) carbonate will react with one mole of sulfuric acid (H_2SO_4) but one mole of copper(II) carbonate will react with two mole of hydrochloric acid (HCl).
   [4] Sulfuric acid (H_2SO_4) contains more hydrogen ions than hydrochloric acid (HCl).
   [5] The two acids are in excess, so the amount of copper(II) carbonate in both experiments determines the volume of gas formed.

3. The initial rate of the reaction involving hydrochloric acid (HCl) is ________ the initial rate of the reaction involving sulfuric acid (H_2SO_4).

   A. less than
   B. equal to
   C. greater than

   Reason/Justification

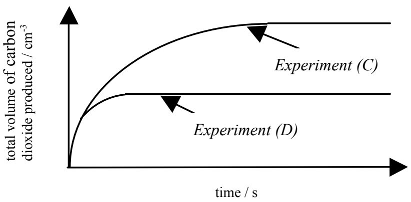
   [1] Both acids have a concentration of 1 mol dm^{-3}.
   [2] The two acids are in excess.
   [3] The two acids are both strong acids.
   [4] There are more hydrogen ions in a volume of 1 mol dm^{-3} hydrochloric acid (HCl) than in the same volume of 1 mol dm^{-3} sulfuric acid (H_2SO_4).
   [5] There are more hydrogen ions in a volume of 1 mol dm^{-3} sulfuric acid (H_2SO_4) than in the same volume of 1 mol dm^{-3} hydrochloric acid (HCl).

For Questions 4 to 6 refer to Laboratory Activity 2

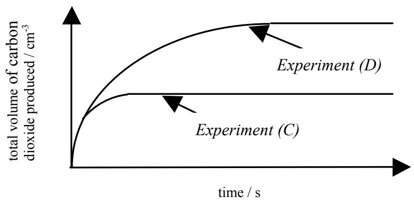
Laboratory Activity 2

4. In Experiment (C), **excess** 1 mol dm^{-3} hydrochloric acid (HCl) was added to a flask containing some powdered marble (calcium carbonate).
In Experiment (D), the same volume of **excess** 0.5 mol dm^{-3} hydrochloric acid was added to another flask containing the same amount of powdered marble as in the first experiment.
Which of the graphs indicates the volume of carbon dioxide produced as the reactions progressed?
Note: Choose one option from A to 3.

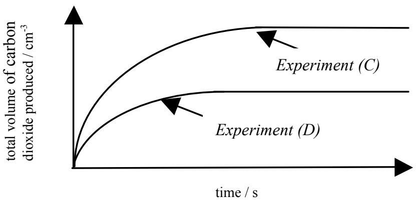
A



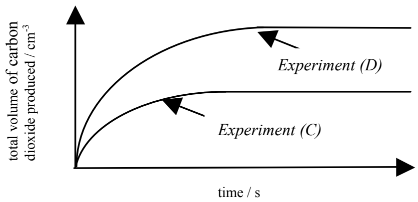
B



C



D



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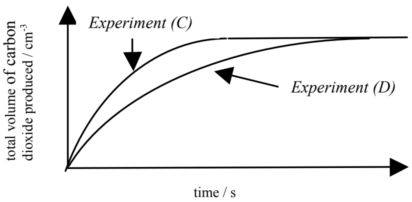
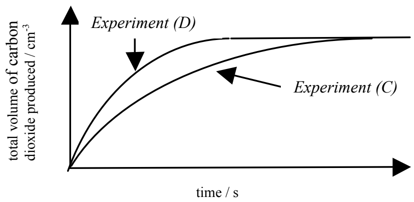


1



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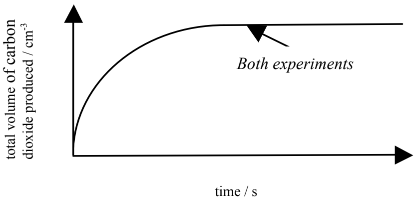


3. If you do not agree with any of the options given, shade 3, write down the question number 4 at the back of your answer sheet and draw your answer.

5. The total volume of gas produced by the reaction involving 1 mol dm^{-3} hydrochloric acid (HCl) is ________ the total volume of gas produced by the reaction involving 0.5 mol dm^{-3} hydrochloric acid (HCl).

A. less than
B. equal to
C. greater than

Reason/Justification

[1] Both 0.5 mol dm^{-3} hydrochloric acid (HCl) and 1 mol dm^{-3} hydrochloric acid (HCl) are strong acids.
[2] The chemical equations in the two reactions are the same.
[3] The two acids are in excess, so the amount of powdered marble (calcium carbonate) determines the amount of gas formed.
[4] There are more hydrogen ions in a volume of 1 mol dm^{-3} hydrochloric acid (HCl) than in the same volume of 0.5 mol dm^{-3} hydrochloric acid (HCl).
[5] There are more hydrogen ions in a volume of 0.5 mol dm^{-3} hydrochloric acid (HCl) than in the same volume of 1 mol dm^{-3} hydrochloric acid (HCl).

6. The initial rate of the reaction involving 1 mol dm^{-3} hydrochloric acid (HCl) is ________ the initial rate of the reaction involving 0.5 mol dm^{-3} hydrochloric acid (HCl).

A. less than
B. equal to
C. greater than

Reason/Justification

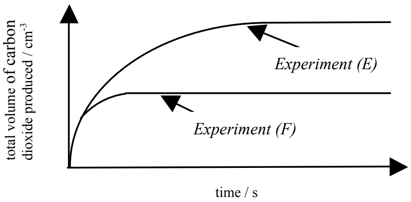
[1] Both acids are in excess.
[2] Both 0.5 mol dm^{-3} hydrochloric acid (HCl) and 1 mol dm^{-3} hydrochloric acid (HCl) are strong acids.
[3] There are more hydrogen ions in a volume of 1 mol dm^{-3} hydrochloric acid (HCl) than in the same volume of 0.5 mol dm^{-3} hydrochloric acid (HCl).
[4] There are more hydrogen ions in a volume of 0.5 mol dm^{-3} hydrochloric acid (HCl) than in the same volume of 1 mol dm^{-3} hydrochloric acid (HCl).

For Questions 7 to 9 refer to Laboratory Activity 3

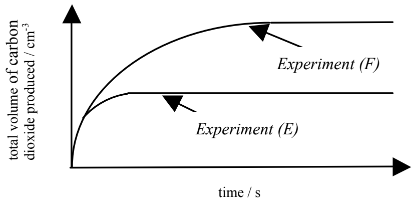
Laboratory Activity 3

7. In Experiment (E), **excess** 1 mol dm^{-3} hydrochloric acid (HCl) was added to a flask containing some powdered marble (calcium carbonate).
In Experiment (F), the same volume of **excess** 1 mol dm^{-3} ethanoic acid (CH_3COOH, a weak acid) was added to another flask containing the same amount of powdered marble as in the first experiment.
Which of the graphs indicates the volume of carbon dioxide produced as the reactions progressed? **Note:** Choose one option from A to 3.

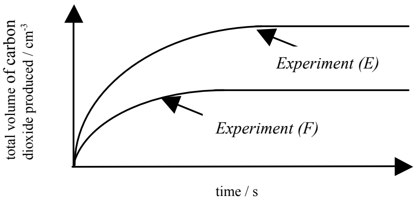
A



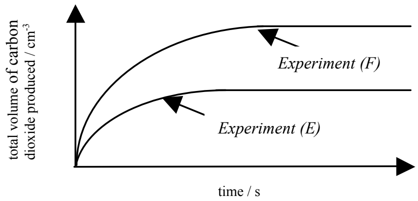
B



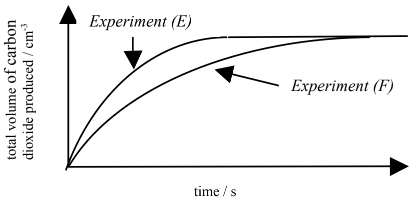
C



D



E



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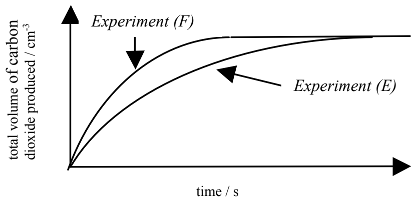

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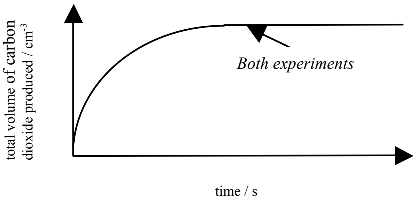


3. If you do not agree with any of the options given, shade 3, write down the question number 7 at the back of your answer sheet and draw your answer.

8. The total volume of gas produced by the reaction involving hydrochloric acid (HCl) is ________ the total volume of gas produced by the reaction involving ethanoic acid (CH_3COOH).

A. less than
B. equal to
C. greater than

Reason/Justification

[1] One mole of powdered marble will react with two moles of ethanoic acid (CH_3COOH) and one mole of powdered marble will also react with two mole of hydrochloric acid (HCl).
[2] The two acids are in excess, so the amount of powdered marble determines the amount of gas formed.
[3] There are more hydrogen ions in a volume of 1 mol dm^{-3} ethanoic acid (CH_3COOH) than in the same volume of 1 mol dm^{-3} hydrochloric acid (HCl).
[4] There are less hydrogen ions in a volume of 1 mol dm^{-3} ethanoic acid (CH_3COOH) than in the same volume of 1 mol dm^{-3} hydrochloric acid (HCl). When the original hydrogen ions present in ethanoic acid are used up, reaction will stop.

9. The initial rate of the reaction involving 1 mol dm^{-3} hydrochloric acid (HCl) is ________ the initial rate of the reaction involving 1 mol dm^{-3} ethanoic acid (CH_3COOH).

A. less than
B. equal to
C. greater than

Reason/Justification

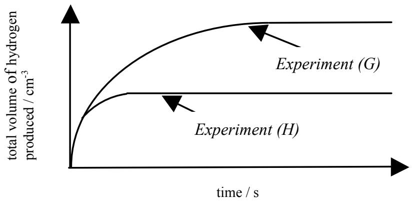
[1] Both acids are in excess.
[2] Both acids have the same concentration.
[3] The strength of an acid does not affect the rate of its reaction.
[4] There are more hydrogen ions in a volume of 1 mol dm^{-3} ethanoic acid (CH_3COOH) than in the same volume of 1 mol dm^{-3} hydrochloric acid (HCl).
[5] There are more hydrogen ions in a volume of 1 mol dm^{-3} hydrochloric acid (HCl) than in the same volume of 1 mol dm^{-3} ethanoic acid (CH_3COOH).

For Questions 10 to 12 refer to Laboratory Activity 4

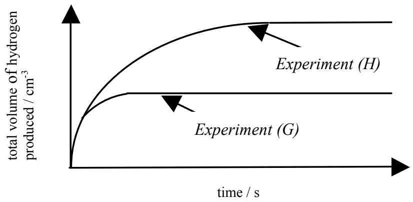
Laboratory Activity 4

10. In Experiment (G), **<u>excess</u>** magnesium powder was added to a flask containing volume of 1 mol dm^{-3} hydrochloric acid (HCl).
In Experiment (H), the same amount of **<u>excess</u>** magnesium powder was added to another flask containing the same volume of 1 mol dm^{-3} sulfuric acid (H_2SO_4) as in the first experiment.
Which of the graphs indicates the volume of hydrogen produced as the reactions progressed? **Note:** Choose one option from A to 3.

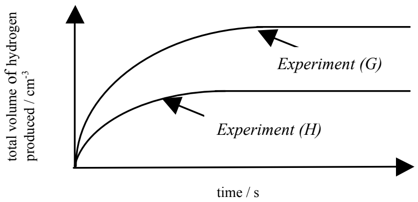
A



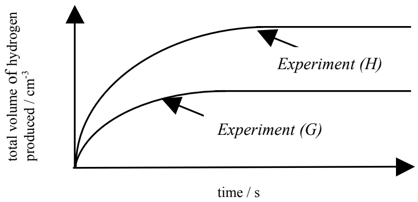
B



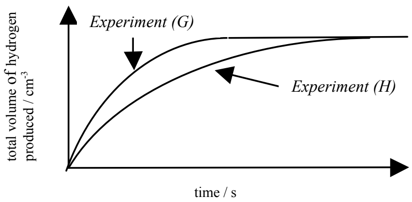
C



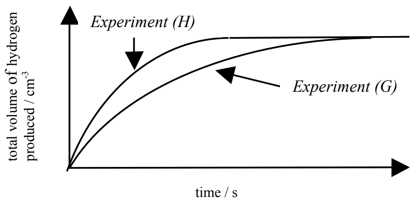
D



E



1



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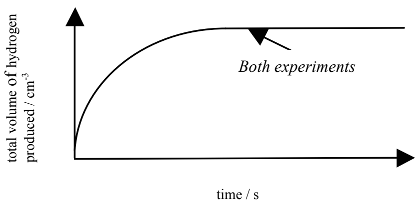


3. If you do not agree with any of the options given, shade 3, write down the question number 10 at the back of your answer sheet and draw your answer.

11. The total volume of gas produced by the reaction involving hydrochloric acid (HCl) is ________ the total volume of gas produced by the reaction involving sulfuric acid (H_2SO_4).

A. less than
B. equal to
C. greater than

Reason/Justification

[1] Both acids are strong acids.
[2] Both acids have a concentration of 1 mol dm^{-3}.
[3] There are more hydrogen ions in a volume of 1 mol dm^{-3} hydrochloric acid (HCl) than in the same volume of 1 mol dm^{-3} sulfuric acid (H_2SO_4).
[4] There are more hydrogen ions in a volume of 1 mol dm^{-3} sulfuric acid (H_2SO_4) than in the same volume of 1 mol dm^{-3} hydrochloric acid (HCl).

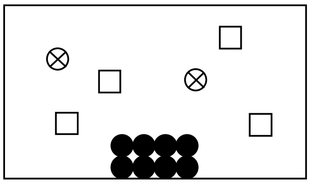
12. The initial rate of the reaction involving hydrochloric acid (HCl) is ________ the initial rate of the reaction involving sulfuric acid (H_2SO_4).

A. less than
B. equal to
C. greater than

Reason/Justification

[1] Both acids are strong acids.
[2] Both acids have a concentration of 1 mol dm^{-3}.
[3] Equal volumes of both acids were added.
[4] There are more hydrogen ions in a volume of 1 mol dm^{-3} hydrochloric acid (HCl) than in the same volume of 1 mol dm^{-3} sulfuric acid (H_2SO_4).
[5] There are more hydrogen ions in a volume of 1 mol dm^{-3} sulfuric acid (H_2SO_4) than in the same volume of 1 mol dm^{-3} hydrochloric acid (HCl).

13. **Excess** magnesium ribbon was added to a beaker containing some 1 mol dm^{-3} of a dilute strong acid, HY. There was a reaction and bubbles of gas were produced. The chemical reaction that occurred is represented by the chemical equation,
$2HY(aq) + Mg(s) \rightarrow MgY_2(aq) + H_2(g)$.
Choose the particulate diagram that represents the relative number of particles left in the beaker after no more gas is produced. **Note:** Choose one option from A to 5. Ignore the water molecules and the ions produced by water molecules.
[○ - H^+], [● - Mg], [⊗- Mg^{2+}], [□- Y^-], [□□ - Y_2^{2-}], [□⊗□- MgY_2]

A


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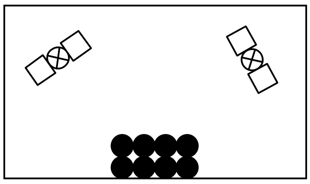

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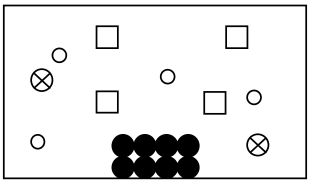

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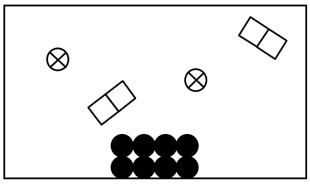

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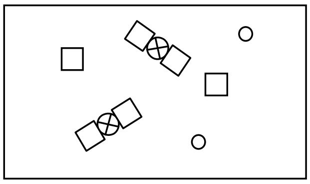

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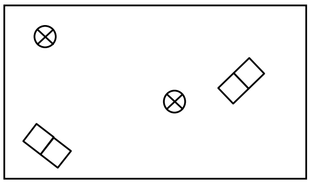

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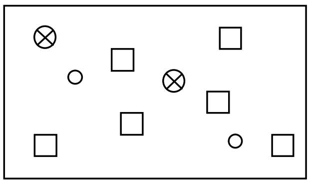

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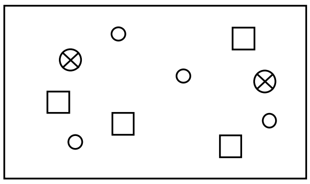

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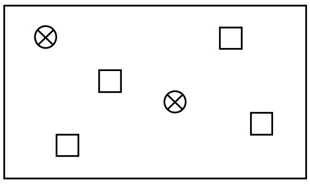

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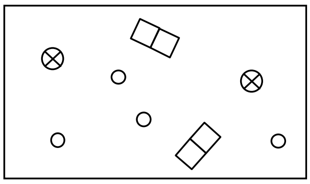
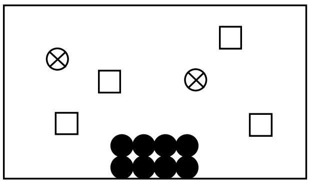


14. **Excess** 1 mol dm^{-3} of the dilute strong acid, HY was added to a beaker containing a piece of magnesium ribbon. There was a reaction and bubbles of gas were produced. The chemical reaction that occurred is represented by the chemical equation,
$2HY(aq) + Mg(s) \rightarrow MgY_2(aq) + H_2(g)$.
Choose the particulate diagram that represents the relative number of particles left in the beaker after no more gas is produced. **Note:** Choose one option from A to 5. Ignore the water molecules and the ions produced by water molecules.

[○ - H^+], [● - Mg], [⊗- Mg^{2+}], [□- Y^-], [□□ - Y_2^{2-}], [□⊗□- MgY_2]

A



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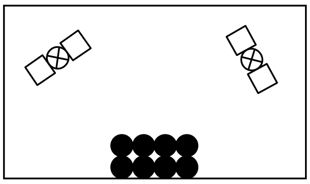

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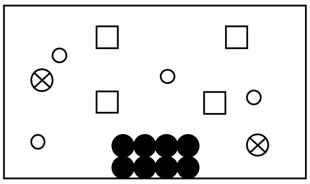

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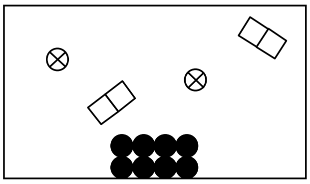
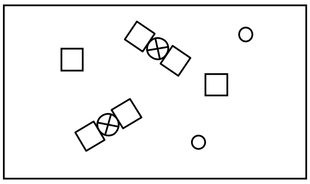


E



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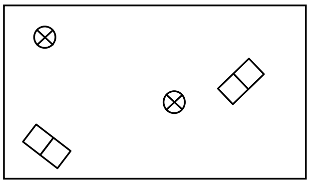

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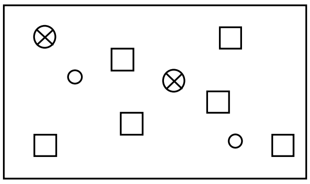

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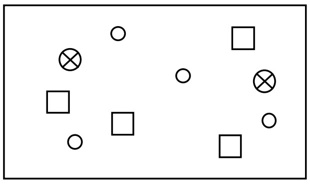

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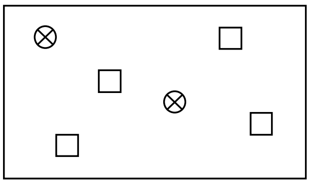

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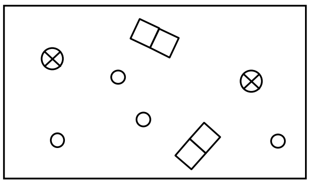

Answers to the questions in the Acid Reactions Diagnostic Instrument

1. 1	5. B3	9. C5	13. A
2. B5	6. C3	10. D	14. 2
3. A5	7. E	11. A4	
4. E	8. B2	12. A5	