2012

Small group work in large chemistry classes: workshops in First Year Chemistry

Glennys O’Brien  
*University of Wollongong, gobrien@uow.edu.au*

Simon B. Bedford  
*University of Wollongong, sbedford@uow.edu.au*

**Publication Details**

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Abstract
First year chemistry classes at UOW are large (>500), the student body is very diverse in academic background and the students are enrolled in a broad range of degree programmes in science and applied science. Although students in Engineering degrees have a separate one semester programme, all other students taking first year chemistry do the subjects CHEM101 (Autumn) and CHEM102 (Spring). The undergraduate degree programmes range from nutrition and dietetics through health and medical sciences to biological sciences, to the degree programs run by the School of Chemistry itself, being BSc(Chem), BMedChem and BNano. The diversity of student intake includes those with senior school chemistry and mathematics, those without who attend a two week Bridging Chemistry intensive and those who have no senior school chemistry background, often lacking formal mathematics as well. Workshops based on Process Oriented Guided Inquiry Learning (POGIL) activities in conjunction with individual formative testing and group based peer assessment have been introduced into First Year Chemistry. We used different workshops formats in CHEM101 and CHEM102 depending on timetabling and other constraints. This has resulted in useful informative comparisons from the staff and student point of view. Extensive student surveying and focus group discussions have given rise to a rich body of commentary. We report our experiences and students' responses and outcomes. This research is being carried out within the context of increasing student numbers, increasing student diversity and major changes in Government policies concerning social inclusion and enablement.

Keywords
large, chemistry, classes, small, workshops, group, first, year, work

Disciplines
Medicine and Health Sciences | Social and Behavioral Sciences

Publication Details

This conference paper is available at Research Online: http://ro.uow.edu.au/smhpapers/952
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Dr Glennys O’Brien
University of Wollongong
Northfields Avenue
Wollongong, NSW 2500
gobrien@uow.edu.au

Dr Simon Bedford
University of Wollongong
Northfields Avenue
Wollongong, NSW 2500
sbedford@uow.edu.au

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First year chemistry classes at UOW are large (>500), the student body is very diverse in academic background and the students are enrolled in a broad range of degree programmes in science and applied science. Although students in Engineering degrees have a separate one semester program, all other students taking first year chemistry do the subjects CHEM101 (Autumn) and CHEM102 (Spring). The undergraduate degree programmes range from nutrition and dietetics through health and medical sciences to biological sciences, to the degree programs run by the School of Chemistry itself, being BSc(Chem), BMedChem and BNano. The diversity of student intake includes those with senior school chemistry and mathematics, those without who attend a two week Bridging Chemistry intensive and those who have no senior school chemistry background, often lacking formal mathematics as well.

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Keywords
First Year Chemistry, group work, POGIL, diversity
1. Introduction

First Year Chemistry courses in Australian universities can be considered to fulfil two purposes: (1) Preparation of students for degrees in chemistry and closely related courses (for example medicinal chemistry, materials chemistry). (2) Preparation of students for degree courses in applied science fields dependent on this fundamental and enabling science. In terms of student numbers alone, this second purpose is significantly the greater in Australian universities.

First year chemistry classes have been increasing in size for some time. This is part of the massification of tertiary education in Australian universities, where student numbers have more than doubled over the past two decades (Norton, 2012). Chemistry reflects the general condition in the sector but also with a suite of issues peculiar to this discipline. First year chemistry students are an increasingly varied group and it is this diversity on top of increasing numbers which places immense strain on the capacity of departments and schools of chemistry to meet their courses requirements. This situation arises in part from Federal government policies as outlined in Transforming Australia’s Higher Education System, developed in response to the Bradley review (Bradley et al, 2008): “by 2025, 40 per cent of all 25 to 34 year olds will hold a qualification at bachelor level or above,” and “20 per cent of higher education enrolments at the undergraduate level will be of people from a low SES background.” (DEEWR, 2009). Diversity in the incoming body of students also arises from the increasing numbers of students lacking senior high school chemistry and mathematics (Lyons & Quinn, 2010; Ainley et al, 2008). Although these students will be largely “consumers” rather than “producers” of science, chemistry is invariably a compulsory subject in their first year. The sector is also undergoing major change in the regulatory and auditing framework, the main development being the formation of the Tertiary Education Quality and Standards Authority (TEQSA) which is currently leading development of standards, auditing procedures and quality assurance (cf QAA). This year, 2012, the latest change is the removal of any enrolment caps on universities, also in response to the Bradley review. Concomitant with policy changes are funding restrictions, and although various projects provide funding for development, base load funding remains the key issue.
First Year Chemistry at the University of Wollongong (UOW) comprises three subjects, CHEM101 and CHEM102 making up the standard first year, and CHEM103 a one semester subject specifically for engineering degrees. CHEM101 and CHEM102 are the first year component of degree courses offered within the School of Chemistry, and these subjects form a compulsory part of a variety of degree programmes in the Faculty of Science and in the Faculty of Health and Behavioural Science. Thus the endpoints for CHEM101 and CHEM102 must cater to a broad range of disciplines. Our overall approach to the curriculum taught in the first year has been based on the principle that students are completing the first tertiary year of this enabling science so the content is comprehensive, not targeted. Over a five year period the incoming student group has grown significantly and the proportion of students entering having completed senior school chemistry is below 50%. Because we do not currently offer two levels of chemistry at the first year with entry dependent on a student’s academic background, all non engineering students take the same first year chemistry subjects, CHEM101 and CHEM102. Thus in CHEM101, CHEM102 and CHEM103, students with senior school Chemistry (HSC CHEM), students who attend the two week intensive Bridging Chemistry and students with no senior school chemistry background are all together.

This paper reports our activities over the past two years developing a series of workshop classes with a relatively high staff : student ratio to address student difficulties in this key foundation subject.

2. Design Methodology

Within a design based research paradigm, a series of workshop activities have been created and implemented, initially as a pilot for CHEM103 in 2010. For subsequent iterations, these class activities have been modified following staff observations and assessment of the pilot practice, in addition to aligning the practice, observations and outcomes with current theories and practices in the literature.

The outcomes of the 2011 CHEM101 and CHEM102 iterations of this project from the student viewpoint have been initially assessed via anonymous voluntary student surveys and focus groups. In addition staff commentary was collected. Outcomes in terms of students’ final marks have been examined, but as no control group was used the only comparisons possible are between years. However comparison of marks between years and therefore different cohorts of students is confounded by other changes, so the students’ final results remain at best a guide.
3. Workshop Design

The workshop design centred on collaborative in-class work with students placed in groups of three. The workshop content and concept based activities were designed on the POGIL principles (Moog and Spenser, 2008). Under this design, in each exercise, the student group is presented with a model which may be a figure, a diagram, a worked example or a chemical structure or other entity tied to a concept. The group explores aspects of the model via a series of critical thinking questions to develop their understanding of the concept. The second phase is application of the concept through more questions or other application activity. Within the group the students are assigned roles to facilitate the activity. The active learning which occurs within this group setting is reported to be highly satisfying to students, as evidenced in a multi-institutional survey of student outcomes via assessment results and the Student Assessment of Learning Gains survey (Straumanis and Simons, 2008).

The assigned group roles used were as follows. The manager (M) was responsible for group time management and task success, looked after the group folder of materials, ensured member participation and was the sole group member to communicate questions to the tutor. The technician (T) supported the group work looking up reference materials, lecture notes etc, performed calculations and collected any “props”. The recorder (R) was responsible for the collective group work as recorded on communal paper, had to be seated centrally and wrote QQ marking with input from both M and T. The roles were very similar to those reported in a variety of POGIL type activities (Moog ed 2008, Brown, 2010). In the CHEM103 pilot a reflector role was included but later discarded as redundant. The POGIL principles are founded on constructivism (Hanson, 2008), with deeper and successful learning promoted when students can be actively involved in discussion with their peers about concepts, principles or certain examples. The constructivist learning model can be used to elucidate some particular benefits of working in groups. Group work allows extension of the working memory for each group member as a collective working memory between them (Kirschner, 2011) and extending on to the communal page where writing is occurring. This is a valuable support to reduce cognitive overload and also assists development of communal schema. The perception filter is another element of the constructivist model, again the group activity brings possible enhancement of perception among the group members, picking up cues that would be missed by the individual.
In addition to the discipline specific learning promoted within this group setting, several elements of graduate qualities (graduate attributes / generic skills) were also introduced and practised. Students could acquire some understanding of group processes as some of these are made explicit via the defined roles. They had the opportunity to experience these different roles and to realize what can help a group to function successfully. The workshops also provided the opportunity to build more effective communication skills and to develop critical thinking and problem solving skills where feedback from peers and from staff was immediately available.

In summary we have designed activities where group work promotes student development of graduate qualities, within the POGIL designed activities students increase their understanding of specific discipline concepts and skills, they link concepts across subject content, and finally they conclude with a low stakes test (quick quiz = QQ) and immediate feedback, all in a two hour workshop.

4. The Workshop Structure

4.1 Pilot CHEM103 2010

The development began with a pilot study in CHEM103, a content dense one semester course. All students in CHEM103 took part, there was no “control” group. Details are given in Table 1.

<table>
<thead>
<tr>
<th>Workshop Parameters</th>
<th>Introductory Chemistry for Engineers CHEM103 2010 (320 students)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time, student : staff</td>
<td>Workshops 2 hrs, 50-55 students, 2 tutors</td>
</tr>
<tr>
<td>Group formation</td>
<td>4/group, informal, randomized, not self selecting, roles assigned</td>
</tr>
<tr>
<td>Workshop materials</td>
<td>Models, questions, problems in student’s subject handbook (Lab Manual)</td>
</tr>
<tr>
<td>Main Activity</td>
<td>No set preworkshop activity, tutor introduction and sum up, group work on POGIL style exercises, tutor moderated where necessary</td>
</tr>
<tr>
<td>Student output</td>
<td>Own notes and group communiqué from recorder</td>
</tr>
<tr>
<td>Assessment / Marking</td>
<td>10 min individual Quick Quiz (QQ), at next workshop, tutor marked</td>
</tr>
<tr>
<td>Materials released online</td>
<td>Guideline answers, selected communiqués, QQ model answers</td>
</tr>
</tbody>
</table>

Table 1: Pilot CHEM103 2010 Workshop Features

The main findings from this iteration were that students without HSC Chem needed more support before taking part in the set activities; the activities were too long, the assessment (QQ) was too late and appeared to be treated by many students as inconsequential; there were too many roles and they were of unequal demand on the group participants. Overall assessment results compared to 2009 did not show marked change. However, comparison is difficult as there was significant variation between the cohorts. Notwithstanding these issues, students were observed to improve in their group work skills in communication, visibly improved some problem solving skills and responded positively to the workshops. The students were not formally surveyed regarding this series of workshops.
4.2 CHEM101 and CHEM102 Workshops 2011

Based on the 2010 pilot, a series of workshops were designed for CHEM101, 2011. While CHEM101 workshops were in delivery, different workshops were designed for CHEM102, where only one hour class times and fewer staff were available.

Tutors (generally PhD students with demonstrating experience) were trained in classroom techniques with POGIL style activities. In addition the tutors were monitored and received regular feedback.

The designs are summarized in table 2 below.

5. The outcomes

Because no control group was included and there were factors which confounded a direct comparison of results between CHEM101 2010 and CHEM101 2011, a direct measure of the impact of workshops on final results was not possible. None the less the total proportion of students passing both CHEM101 and CHEM102 did increase by approximately 10% from 2010 to 2011.

Student evaluation of the workshops in CHEM 101, 2011 was gathered by survey using Likert scale questions and free comment. Students were asked to rate the different modes of learning activity or resources in CHEM101 (lectures, workshop, laboratory class, Peer Assisted Study Scheme PASS, private study, textbook etc) as useful for their learning. The modes were not compared to each other; rather each individual mode was independently rated 1-5. Workshops ratings were significantly higher, that is, rated more useful, than all other modes of activity (n=187, p=0.05). Student commentary aligned with the Likert scale results. In 162 comments from students responding to the question “What was the single best thing in CHEM101” 35 comments named workshops specifically, being the most frequently named entity in the responses to that question. Student comments about challenges found in workshops (14 comments) covered three aspects; (1) students wanted to be able to write their own notes on all problems and not leave writing solely in the hands of the recorder, (2) some students expressed dissatisfaction with some tutors, (3) some students found the QQ stressful and would have preferred assessment later.
### CHEM101 2011 (600 students)
- 3 hr workshop each fortnight, compulsory

### CHEM102 2011 (520 students)
- 1 hr workshop each week, compulsory

#### Time, staff
- **CHEM101**
  - Part A 1 hr, 10-14 students, Tutor A
  - Part B 2 hrs, 21 students, Tutor B
- **CHEM102**
  - Part A preparation before class
  - Part B 1 hr, 50-55 students, 1 Tutor

#### Group formation
- **CHEM101**
  - Part A, informal, support for B, N students
  - Part B, 3 / group, students preselected on academic background
  - Groups comprised H, B, N (75% groups); some groups H, N, N. No groups N, N, N.
  - Groups fixed for semester.
- **CHEM102**
  - Part A, 3 / group, groups informal and self selecting.
  - Groups fixed for semester.

#### Roles
- **CHEM101**
  - Roles, (M, T, R) assigned, then rotated.
- **CHEM102**
  - No roles assigned

#### Workshop materials
- **CHEM101**
  - Part A: questions and problems in each student’s subject handbook formatted for answers / notes.
  - Part B: models, questions, problems in each student’s subject handbook formatted as in Part A
- **CHEM102**
  - Part A: discussion, questions and problems in subject handbook formatted for answers / notes.
  - Part B: one worksheet per group, students made group or individual notes from sheet.

#### Main activity
- **CHEM101**
  - Part A: tutor introduction and sum up, group work on set exercises, tutor moderated where necessary
  - Part B: see workshop timeline detailed below
- **CHEM102**
  - Tutor introduction and sum up, group work on set exercises, tutor moderated where necessary

#### Student output
- **CHEM101**
  - Recorder produces collective answers, retained in group folder, folder available in lab classes.
- **CHEM102**
  - Individual notes from common worksheet problems / exercises.

#### Assessment / marking
- **CHEM101**
  - 10 min individual QQ, at end of workshop, peer marked in groups, tutor moderated after workshop
- **CHEM102**
  - No QQ

#### Materials released online
- **CHEM101**
  - Guideline answers to workshop Part A and Part B, QQ model answers
- **CHEM102**
  - Part A – none, Part B guideline answers, Part C additional post workshop practice materials as Q&A

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1. Student background HSC Chem (denoted H), Bridging Chem (B), no known senior school chemistry (N)
2. Timeline of activities in main 2 hr workshop:
   - 60 - 70 mins set POGIL questions group activity, roles assumed;
   - 5 – 10 mins link mapping, students write in journal notes in subject handbook;
   - Break, leave the classroom;
   - 10 min individual Quick Quiz QQ; 15 min group based peer marking with guideline answers;
   - Feedback: student views own marked QQ.

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### Table 2: CHEM101, CHEM102, 2011 Workshop features

Student evaluations of CHEM102 workshops provided an interesting second round of commentary. As well as staff conducting focus groups for feedback, a total of 168 comments on workshops were gathered via anonymous voluntary survey. Fewer than half the comments were favourable, most notably comments specifically related to the staff student ratio. Students also commented that as groups were self selecting allowing friends to congregate, this allowed more informal social talk, less focus on the subject and less work achieved. Students also commented on the one hour duration being noticeably and undesirably shorter. Some comments reflected the lack of assessment (QQ) as a driver for performance within the workshop.
6. Discussion

Based on students evaluations, the workshops have proven successful, and from students and staff feedback we have clear indications of where to modify the design in order to change those aspects found challenging. The single most challenging aspect regarded students writing. It was clear that restricting group writing to the recorder for POGIL exercises was not popular. Students reported having strong habits of writing to learn at school, in addition writing while working through a problem extends the working memory and aids schema formation. This was further exacerbated by supplying the POGIL activity materials in each student’s handbook so there was a strong temptation to fill in the gaps. On the other hand, three students concentrating on individually writing their own response in their handbooks quickly reduced the intensity and efficiency of the collaborative work. In modifying the design of the POGIL activities for 2012 in response to this, two elements will be introduced: (1) In response to students requests to be able to make individual notes within the workshop, the POGIL activities will be broken up, with tutors incorporating specific times for group work to pause, summing up to be done and students to make their own individual notes. (2) To strengthen the recorder’s role and the value of the recorder’s communal notes on worksheets, worksheets with all set materials will be distributed one set per group, by the tutor at the beginning of the workshop. After the workshop the completed group work sheets will be made available to the group as soft copy scanned to pdf.

The other element of concern from student feedback was the assessment (QQ) given immediately before the end of the workshop, some students informally commenting that they would prefer assessment at a later time. This was not surprising, however our experience in CHEM102 workshops showed how important a driver the quick quiz proved to be. In addition the students themselves came to realise this. A surprising comment from more than one student was that repeated small assessments helped them adjust to assessment, which in turn made midterm tests and final exams less of a stressful hurdle. The staff do consider that QQ design is critical, it must be low stakes – two of the three questions being accessible to virtually all and worth only a small portion of final marks, so that at least partial success is perceived as achievable by all. Success in the QQ assessment will be tied to the value of the workshops in the student mind.
7. Conclusion

Workshop activities based on a POGIL design have been successfully incorporated into teaching in first year chemistry, with a very favourable student response. The micro managed programme of activity used in CHEM101 was favoured by students over the much looser arrangements of CHEM102. It was most interesting to note that although students had experienced the more highly managed workshops in CHEM101, and later appreciated them, in general they did not or could not bring that level of control into their CHEM102 workshops of their own accord. The students needed that level of management to be set up for them. Perhaps that is not so surprisingly, by the end of CHEM101, they had experienced only six workshops in only one group. More practice was required to develop these generic skills.

Modifications of the workshop design have already been incorporated into the third iteration of this program. External review and more robust survey tools will be included in further evaluations.

8. References


