Bridging courses: Good learning environments for engaging students?

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Abstract

Bridging courses designed to improve students’ experience and to develop knowledge required for successful tertiary study are relatively widespread; however, little work has been done examining their effectiveness. The current study focused on students who were undertaking a first year chemistry unit of study at the University of Sydney designed specifically for students with little or no prior knowledge of chemistry. Students were grouped according to their chemistry backgrounds and it was established that those students who completed the bridging course academically outperform those with no prior chemistry study. Both academic and non-academic factors related to the bridging course, such as students’ levels of prior knowledge and their confidence in their own learning, are considered.

Introduction

The backgrounds brought by students to tertiary study are becoming increasingly diverse, both with respect to their prior knowledge of their domain of study and their experiences of studying and life in general (Krause, Hartley, James, & McInnis, 2005). For students with little prior knowledge in a domain, bridging courses offer an efficient and cost-effective way to help students to address any deficiencies in their prior knowledge. However, such courses are only worthwhile if they do promote understanding of the domain and provide a foundation for future studies. This paper reports on a detailed investigation of the efficacy of the chemistry bridging course at the University of Sydney.

The bridging course is an intensive seven day course catering to about 200 students; it is conducted shortly before the commencement of semester and consists of 13 one hour lectures, delivered in a traditional setting, each followed by a two hour tutorial. These tutorials are conducted in groups no larger than eight, with a post-graduate student tutor, and allow students to complete practice questions on the material covered in the preceding lecture. Tutors attempt to establish a collaborative environment by having students work together when they encounter problems, and by encouraging questions – this design reflects literature findings that tangibly demonstrating that effort is valued helps to motivate students (Ames & Ames, 1991), reduces social comparison (Skinner & Belmont, 1993) and promotes students’ adoption of mastery goals (Wolters, 2004). The bridging course covers basic chemical concepts and terminology, writing and balancing chemical equations, stoichiometric calculations, and provides an introduction to acid / base and redox chemistry. Participation in the bridging course, although strongly recommended for students with no previous study of chemistry, is voluntary, and there is no formal bridging course assessment.

Indirect empirical data from previous work (Read, George, Masters, & King, 2004) suggest that participation in this bridging course is associated with enhanced student performance. That work examined the end-of-semester exam performance of students, categorised by
background knowledge, with a broad, catch-all group used for students with weak backgrounds; students who had completed this bridging course were included in this group. For the 2003 cohort of the Fundamentals of Chemistry 1A unit (the unit examined in this work), Youl, Read, George, Masters, Schmid, and King (2005) reported that students with weak backgrounds achieved an average end-of-semester exam score which was 13 marks above that of their no prior chemistry counterparts – this performance level is comparable to that of students who had studied chemistry in their final year of high school. Unfortunately, the use of a catch-all category in that work makes it difficult to examine the bridging course in isolation, and for this reason, this systematic examination has been undertaken.

Surprisingly, despite bridging courses being relatively common, there have been few studies of this type of university preparation course. In the domain of chemistry, a literature search reveals three studies conducted about 30 years ago (Meckstroth, 1974; Walmsley, 1977; Krannich, Patick, & Pevear, 1977), and three more recent studies (Mitchell & de Jong, 1994; Chittleborough, 1998; Jones & Gellene, 2005). Unfortunately, these provide only limited insight into courses of the type covered in this research, as they examined courses with very small cohorts (around 20 students), or the courses involved timeframes as long as a semester – with the exception of our previous work, no studies have been found which deal with short duration, intense programmes, and which deal with comparatively large student cohorts.

For the effect of a bridging course to be examined in detail, consideration of only the academic performance of the participants is insufficient. To address questions of students’ understanding, qualitative methods which examine the students’ perspectives are needed. Whilst the studies mentioned above provided answers to the research questions that they posed, none of them were designed to provide such detailed information about learning in the context of a bridging course. The aims of this study are: firstly, to investigate the effect of participation in the chemistry bridging course on students’ academic performance; secondly, to examine whether such participation equally promotes understanding of all areas covered; and, finally, to explore reasons for any observed differences in students’ performance.

Methods

Data were collected from the 2005 student cohort in the unit Fundamentals of Chemistry 1A (n = 318); this unit has no formal assumed knowledge of chemistry, and is designed for mainstream science students whose chemistry background is weak. However, as admission to the unit is not restricted, the cohort does include students who have completed chemistry for their Higher School Certificate (HSC). Four principal categories of students’ background knowledge were used – Strong Background (SB, students who have completed at least HSC chemistry or its equivalent); Bridging Course (BC, students who completed the University of Sydney chemistry bridging course in 2005); No Prior Chemistry (NPC, students who have not studied chemistry beyond that covered in junior high school science classes); and Repeat Students (students who had previously failed a first year university chemistry unit).

Sources of data included surveys, students’ scripts from the end-of-semester exam (the largest assessment task), and interviews. The surveys included Likert-scale and open-ended questions concerning students’ perceptions of their preparedness for their studies, and of the difficulty of the unit. Exam scripts provided both quantitative (unscaled results) and qualitative data, by analysing responses for commonalities of methods and approaches. A series of three interviews were conducted with volunteers selected from the NPC, BC, and SB groups, and were conducted early in semester, near the end of semester, and after publication.
of the exam results. Interview topics included students’ experiences of the unit; preparation for tertiary studies; and, experience of, and performance in, the end-of-semester exam.
Results and discussion

Study participants

All students enrolled in the unit were invited to participate in the study by responding to a survey, conducted during the week 3 laboratory session; respondents were also asked to permit access to their exam scripts, and indicate whether they were willing to participate in the interviews. A total of 216 (67.9 %) students participated in the study. An analysis of exam grade band distributions shows that there were no statistically significant differences between the academic performance of the respondent and non-respondent groups ($\chi^2 = 2.85$, df = 4, $p = 0.583$), nor is there any significant difference in average exam marks ($t_{316} = 1.08$, $p = 0.281$). The distribution of students amongst the NPC, BC, SB, and a catch-all ‘other’ background category (which included Repeat Students, as there are too few of them to form a separate category for valid $\chi^2$ analysis) shows that the sample population is consistent with the entire student cohort ($\chi^2 = 3.54$, df = 3, $p = 0.316$). A lower response rate of 53.5 % (n = 144) was obtained for the week 13 survey. A total of 58 students enrolled in the unit completed the bridging course, and more than half of them responded to each of the surveys (Survey 1, n = 37; Survey 2, n = 31). A total of 12 students participated in the interviews, spanning the NPC (3 female, 2 male), BC (2 female, 2 male), and SB (2 female, 1 male) groups. Qualitative analysis of exam scripts was completed for all students who participated in the week 3 survey and gave consent for their scripts to be so analysed – particular attention was given to scripts from students in the NPC (n = 78), BC (n = 37), and SB (n = 49) groups.

Prior knowledge and examination performance

The academic performance of students in each of the background knowledge categories in the end-of-semester exam was analysed – Figure 1(a) shows the means and 95 % confidence intervals for the average performance of each group, whilst the distributions of exam grade bands are shown in Figure 1(b). One-way ANOVA confirms that the academic performance of students with different levels of background knowledge is not the same ($F_{3,268} = 5.83$, $p < 0.001$), and it is clear from Figure 1(a) that the trend is for higher performance amongst students with greater background knowledge. SB students on average significantly outperformed NPC students ($t_{196} = 3.93$, $p < 0.0002$), and BC students achieved results between these groups. BC students achieved higher merit grades for their exam performance at a rate (34.5 %) consistent with that of their SB counterparts (34.6 %), substantially outperforming the NPC students (21.4 %). However, the raw exam mark failure rate of BC students (39.7 %) was more similar to the NPC students (42.8 %) than it was to the SB students (21.0 %). These results are consistent with the trends seen in the 2003 cohort (Read et al., 2004; Youl et al., 2005) and, although the absolute performance differences are not as large, do support the conclusion that participation in the bridging course is associated with improved academic performance. It is considered unlikely that the performance differences between the NPC and BC students might be due to differences in initial motivation, as most NPC students were either unaware of, or were unable to attend, the bridging course, and many stated that they would have attended it had they been able. Furthermore, these results are also consistent with previous research on the influence of prior knowledge on academic performance in chemistry (BouJaoude & Giuliano, 1991, 1994), a link which is also well established in many other domains (Dochy, Segers, & Buehl, 1999).

The performance of Repeat Students, who have previously failed either this unit or another first year university unit which covered similar content, is particularly poor. As this study
was not designed to study the performance of Repeat Students, this result will not be further investigated; however, it does clearly illustrate that these students find repeating this unit very challenging, and that undertaking a detailed study of their experiences might be instructive.

![Figure 1: Average raw exam marks (a) and raw exam grade band distributions (b) for different levels of prior knowledge in Fundamentals of Chemistry 1A, 2005.](image)

Our findings are consistent with the constructivist view of learning, which recognises that the learners are active participants in the learning process, and must interpret information in order to make sense of it and to construct a useful knowledge schema (Bodner, 1986; Palincsar, 1998). As a consequence and as Ausubel argued as long ago as 1968, “the most important single factor influencing learning is what the learner already knows” (p. 18), as this knowledge provides the framework used to interpret new information (Leder, 1993), and will also influence approaches taken to learning (Elliott & Dwyer, 1995; Gijlers & de Jong, 2005). This accounts for the observed trend amongst students taking the unit for the first time, and also illustrates the way in which prior knowledge which is inconsistent with accepted conclusions within a domain can interfere with learning. In the domain of chemistry, de Astudillo and Niaz (1996) and Niaz, Aguilera, Maza, and Liendo (2002) have described the influence of prior knowledge in generating misconceptions, and there has also been extensive discussion of misconceptions and conceptual change in the science education literature (Posner, Strike, Hewson, & Gertzog, 1982; Schnotz, Vosniadou, & Carretero, 1999; Limón & Mason, 2002). It seems clear that students with higher levels of background knowledge of chemistry are better able to make sense of newly encountered chemistry material.

**Students’ perceptions of the difficulty of the unit, and their preparedness for it**

Both the week 3 and 13 surveys used five item Likert scales to ask students how well they thought their previous study of chemistry had prepared them for beginning study in Fundamentals of Chemistry 1A. They were also asked how difficult they had found the unit to that point. The results are summarised in Table 1, where the end items have been merged. Related data are presented in Figure 2, which was constructed by assigning each Likert scale item an equally spaced value, and then finding the average for each of the NPC, BC, and SB groups. Only students who responded to both of these surveys have been included in these results, so that the week 3 and 13 responses are directly comparable.

There is a clear trend evident in these results – students with higher levels of prior knowledge had less difficulty with the unit, and reported being more prepared for their studies. It is also clear that the perceptions of students change over the semester, with all categories finding the material being studied more difficult as the semester progressed, and being less confident in their preparedness. Such a finding is consistent with the challenge presented by the material
increasing over time. Finally, responses from the BC group are between those of the NPC and SB groups, which is consistent with a ‘bridging of the gap’ effect for these students.

<table>
<thead>
<tr>
<th>Background Knowledge</th>
<th>Perception of difficulty of unit†</th>
<th>Perception of preparedness for unit‡</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>Very Difficult or Difficult</td>
</tr>
<tr>
<td>No Prior Chemistry</td>
<td>38</td>
<td>60.5 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.6 %</td>
</tr>
<tr>
<td>Bridging Course</td>
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<td>5.0 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50.0 %</td>
</tr>
<tr>
<td>Strong Background</td>
<td>21</td>
<td>4.8 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>61.9 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Perception of preparedness for unit‡</th>
<th>n</th>
<th>Very Poorly Prepared</th>
<th>Adequately Prepared</th>
<th>Well or Very Well Prepared</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Prior Chemistry</td>
<td>23*</td>
<td>52.2 %</td>
<td>43.5 %</td>
<td>4.3 %</td>
</tr>
<tr>
<td>Bridging Course</td>
<td>20</td>
<td>10.0 %</td>
<td>35.0 %</td>
<td>55.0 %</td>
</tr>
<tr>
<td>Strong Background</td>
<td>21</td>
<td>14.3 %</td>
<td>28.6 %</td>
<td>57.1 %</td>
</tr>
</tbody>
</table>

† Percentages on the top rows (*shown in blue*) are from the week 3 survey; those on the bottom row (*shown in orange*) are from week 13 survey. A pale yellow background has been placed behind the largest figure in each group.

‡ Many No Prior Chemistry students did not respond to this question on the week 3 survey.

Table 1: Students’ perceptions of the difficulty of the unit, and their preparedness for it, from responses to week 3 and week 13 surveys.

Figure 2: Students ‘average’ perceived difficulty of Fundamentals of Chemistry 1A (a), and their ‘average’ preparedness for it (b), from results from the week 3 and 13 surveys.

Considering the week 3 data, BC students found the early material considerably easier than did their NPC counterparts, and reported levels of difficulty slightly below those of the SB group. BC students also reported preparedness levels consistent with the SB group, substantially higher than those from the NPC group. The week 3 survey asked BC students to comment on ways in which the bridging course had helped them in their studies in Fundamentals of Chemistry 1A. Two clear themes emerged from the 37 responses, with 13 comments relating to revision of bridging course content, and 21 comments indicating that bridging course studies had provided them with a foundation for their understanding of new material. The following are representative examples of the two types of comment:

“So far the unit of study has been revision of topics covered in the bridging course.”

“It has given me a solid grounding in chemistry prior to the commencement of the semester.”

The week 13 responses to the difficulty item (Figure 2(a)) suggest a similar level of difficulty across the groups; however, it is clear from Table 1 that a neutral response (‘neither difficult nor easy’) was more common amongst the BC and SB group students than it was amongst the NPC students. The week 13 responses to the preparedness item are instructive: 90.5 % of SB students were willing to describe their preparation for Fundamentals of Chemistry 1A as at least adequate, with 80.0 % of BC students sharing this opinion. By contrast, only 21.7 % of

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NPC students were willing to describe their preparation as adequate, and none described themselves as well or very well prepared. This result provides useful guidance for further alignment of the unit design with the needs of NPC students, for whom it was developed. It also illustrates the potential of a brief but intense bridging course to prepare students for studies at a tertiary level, an illustration that is reinforced by qualitative survey data indicating that participation in the bridging course provided students with increased confidence:

“It has given me confidence in studying chemistry. I feel more comforted having the ability to understand lecture material.”

The literature on motivation contains substantial discussion of self-efficacy, which was defined by Bandura (1997, p. 2) as “beliefs in one’s capabilities to organise and execute courses of action required to manage prospective situations”. It has been well established that there are strong correlations between self-efficacy beliefs and academic performance (Zimmerman, 2000; Pajares & Schunk, 2001). The enhanced level of perceived preparedness, coupled with increased confidence, suggests that the bridging course helps students’ to improve the self-efficacy. This is a potential pathway leading to the observed improvement in academic performance, which may be operating in parallel with knowledge development associated with bridging course coverage of relevant fundamental chemical concepts.

Performance on qualitative and quantitative questions

Students’ comments during the interviews suggest that many students had difficulties with calculations in the area of stoichiometry, and that this difficulty was even experienced by SB students, who would have studied such calculations during their HSC studies. These interviews also provide evidence that the bridging course may have enhanced students’ understanding in this area, with BC student Ryan† commenting

“[the Bridging Course] really got the idea of stoichiometry in my head, and then the [Fundamentals of Chemistry 1A] lectures, basically just reinstated the ideas.”

In order to investigate whether students of different backgrounds performed differently on different types of questions, and to investigate students ability to answer stoichiometric questions, students’ performance on a set of qualitative and a set of quantitative questions from the end-of-semester exam were compared. The results are shown in Figure 3. The quantitative questions required students to balance a chemical equation, determine the mass of solute required to prepare a given solution, and determine the volume of a base required to neutralise a given quantity of acid. The qualitative questions required students to provide explanations of chemical phenomena in the areas of resonance, bonding, the standard enthalpy of formation, and dynamic equilibrium. Each set of questions was worth a total of eight marks, and came from the short answer part of the exam paper.

There is a clear trend of improved performance with increasing prior knowledge on quantitative questions evident in Figure 3. One-way ANOVA confirms a statistically significant difference in performance between these groups ($F_{2,253} = 14.6, p < 0.0001$), and independent sample $t$-tests confirm that SB students outperformed BC students ($t_{137} = 2.26, p = 0.0254$), who in turn outperformed NPC students ($t_{173} = 2.38, p = 0.0184$). These results are consistent with the bridging course facilitating improved performance in this area, but the extent to which differences can be attributed to cognitive (knowledge) factors rather than non-

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† A pseudonym; all student quotes from interviews are identified only by pseudonyms
cognitive factors (such as enhanced confidence and self-efficacy) is not clear.

**Figure 3:** Mean and 95% confidence interval for academic performance on a selection of qualitative and quantitative questions from the end-of-semester exam.

In order to better understand this effect for BC students, detailed qualitative analysis examining approaches and methods to a stoichiometry question was completed. The question analysed was “What volume of [0.200 M NaOH] would be required to neutralise 50.0 mL of 0.100 M hydrochloric acid solution?” and comes from the end-of-semester exam. Figure 4 shows the approaches taken by students in the NPC, BC, and SB groups to this question, noting whether there was evidence of the application of an algorithm, or whether a conceptual approach (based on an appreciation of the underlying principles) was used. This distinction reflects the division of problem solving approaches in the chemistry education literature (Herron, 1975; Sawrey, 1990; Pickering, 1990) between strictly algorithmic problem solvers (who can apply an algorithm without necessarily understanding it), conceptual problem solvers (who apply their understanding, without reference to a formal algorithm), and combination problem solvers (who use a combination of approaches, and who may choose to apply an algorithm, but who also understand its underlying principles).

**Figure 4:** Distribution of students’ approaches to a stoichiometry question.

The difference in distribution between the NPC, BC, and SB students is statistically significant ($\chi^2 = 20.4, \text{df} = 6, p = 0.00232$), and the trend is clear. Around 85% of students in each group attempted to use an algorithmic approach, with students with more prior knowledge experiencing a greater degree of success. The rate of conceptual based approaches was consistent across the groups, and includes only a small number of students.

Students can often successfully complete algorithmic questions without having an adequate understanding of the chemical concepts involved (BouJaoude, Salloum, & Abd-El-Khalick, 2004). As a consequence, an answer which includes a correct application of an algorithm

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may not allow a strictly algorithmic problem solver and a combination problem solver to be distinguished. Properly designed interviews can not only provide insight into the experiences of students, but also allow student understanding to be gauged, and make it possible to distinguish between such students. Ryan, for example, discussed how he had learnt about the algorithm, which he (correctly) used, during bridging course lectures. He noted how the structure of the algorithm made such questions much easier to complete; more importantly, his discussion of it made it clear that he understood the stoichiometric concepts that underlie the algorithm. This provides some evidence that the BC students do not merely have better developed algorithmic skills than NPC students, but that they have also developed some meaningful understanding of the underlying principles.

The uniformly poor performance ($F_{2,253} = 0.0092, p = 0.91$) of all groups on the qualitative questions, as shown in Figure 3, is also worthy of comment. It is perhaps not surprising that NPC and BC students should perform similarly on these questions, as the bridging course provides relatively little practice of such questions. However, bonding concepts are studied in HSC chemistry, and SB students should also have considerably more experience with explanation-type questions, making their poor performance on these questions surprising. This finding was unexpected, and is worthy of detailed investigation in the future.

Learning environment and student engagement – tutorials

Student understanding develops most effectively in learning environments which are conducive to the active construction of knowledge. Evidence from the first set of interviews suggests that BC students found the bridging course tutorials to be very positive learning experiences. For example, Thomas commented that the bridging course tutor knew the students’ level of “progress” and “ability”, and that the tutorials had a “strict structure” where everyone was working; Karen commented that “If I didn’t understand it I could just go ‘I need help!’”; and, Therese commented on the opportunities presented for students to develop their own meaningful understanding of the material covered in bridging course lectures:

“... in the lectures, we would get information, but sometimes we didn’t really understand the concept well, whereas when we had to actually apply that knowledge [in the tutorials], it would become, perhaps easier, I’d say because, we realised what we had to do and everything.”

A constructivist view of learning, as described above, is adopted in this research; the learning process involves individual knowledge construction and sense making (Bodner, 1986), and thus requires cognitive engagement and effort on the part of the learner. The bridging course teaching sequence, with each lecture followed by a two hour small group tutorial, is designed to assist students with this process, and the small group size provides the tutor with the chance to address misunderstandings whilst students schemata are being constructed, thereby reducing the development of misconceptions. Learning is also significantly mediated by social factors, such as interactions with peers and teachers (Brown, 1994), which is the reason that bridging course tutors encourage collaboration within their groups. Learners at similar cognitive levels have the opportunity to effectively co-construct an understanding of new material (Palincsar, 1998), and can also help to provide a ‘scaffold’ assisting each to reach a higher level of cognitive functioning (Clarkson & Brook, 2004). Vygotsky (1978) coined the term “Zone of Proximal Development” to describe such a circumstance; this zone refers to the difference between the level of cognitive achievement possible for a student working alone, and that which the student can achieve when their learning is scaffolded (John-Steiner & Mahn, 1996). The bridging course tutorials provide students with the opportunity to develop their understanding in a supportive social environment, scaffolding each other through their
zones of proximal development; such environments have been shown to enhance learning outcomes (Brown & Palincsar, 1989; Coe, McDougall, & McKeown, 1999).

The potential impact of a learning environment on student motivation is an important consideration if student engagement is to be fostered. In writing about motivation, Paris and Turner (1994) reported that environments which offer students meaningful choice and control, provide the opportunity for collaboration, and provide appropriate challenge foster motivation and engagement, and the benefits of collaboration for motivation have also been noted by others (Tang, 1993; Slavin, 1996). The motivation literature has also noted that a self-perception of competence is a basic need (Ames & Ames, 1991), and asking questions risks undermining this perception as it raises the possibility of being publicly seen to be wrong – this is a particular problem in tutorials in large groups, as the following comments make clear:

Therese: “…also the [Fundamentals of Chemistry 1A] tutes, they’re good like, in a way, but the thing I don’t really like is we’re in a really large group, whereas, in the bridging course, it was just seven of us in each tute group, and you could ask more questions kind of thing.”

Ryan: “…because it just seems that if you have a smaller number of people in a group… you’re probably more willing to, like, answer questions and, if you have specific questions, you’re not too shy to ask them out loud or something…”

Large group tutorials also risk becoming more monologue than dialogue, thereby losing “that personal interaction” as Thomas, a BC student, put it. Michael, an SB student, commented:

“The [Fundamentals of Chemistry 1A] tutorials … haven’t been that good. You go in and the tutor works through the answers to the assignments on the board… and so, there’s not that much I get out of it.”

Students’ experiences of the Fundamentals of Chemistry 1A tutorials indicate that the large groups involved and the resulting lack of student-student and student-tutor interaction leaves students feeling uncomfortable asking questions, and as a consequence students are not being as effectively engaged in the learning process. In contrast to the learning environment of the bridging course tutorials, this reduced level of engagement, coupled with fewer opportunities for scaffolding, detracted from the quality of the learning environment in the Fundamentals of Chemistry 1A tutorials in 2005. Partly for these reasons, a new small group tutorial program has been introduced in 2006, designed to provide for more engaging learning environments.

Conclusion

This research has shown that participation in the chemistry bridging course at the University of Sydney is associated with improvements in academic performance in tertiary study, which illustrates the beneficial effect that such short but intense preparatory courses can have. Data have been presented showing that these benefits include improved understanding of material studied, as well as improved confidence and enhanced academic self-efficacy, and that these benefits do not appear to be attributable to differences in initial motivation. These effects are most pronounced in relation to material which students find difficult, where there are cognitive benefits when the opportunity to review and reconsider material a second time is presented. This opportunity appears to facilitate the construction of coherent schema, affording students a deeper understanding of the principles related to the concept, and illustrates the importance of providing students with a foundation for future studies. These results also highlight the learning benefits which flow from small group tutorials, especially when an environment which fosters student engagement is used.