Chemistry Education Research and Practice

Accepted Manuscript

ROYAL SOCIETY OF CHEMISTRY

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The Impact of Nursing Students' Prior Chemistry Experience on Academic Performance and Perception of Relevance in a Health Science Course

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Nursing students have typically found the study of chemistry to be one of their major challenges in a nursing course. This mixed method study was designed to explore how prior experiences in chemistry might impact chemistry achievement during a health science unit. Nursing students (N=101) studying chemistry as part of a health science unit were divided into three groups based on prior chemistry experience and into three groups based on their academic performance in the health science unit. Although there was no significant difference in the mean achievement scores for students who had completed a 3-day chemistry bridging course (BC) and students who had not studied chemistry since year 10 (PC), 52.3% of the PC group were low achievers compared to 33.3% of the BC group. The BC students were more evenly distributed across the academic performance categories than was the case for PC students. Students who had previously studied senior chemistry at high school level (SC) had a mean achievement score which was significantly greater than that obtained by BC and PC students. Students described their chemistry experiences in the context of academic performance using terms that related to: basic chemistry as a foundation for further study; the use of different representations in chemistry; and the language and logical structure of chemistry. There were differences and similarities in the way the different prior chemistry experience groups related to these issues. Low chemistry achievers became less optimistic about the relevance of chemistry to nursing as the course proceeded.

Key Words Academic performance; Bridging course; Chemistry education; Cognitive overload; Nursing chemistry; Prior chemistry experience; Relevance of chemistry

Introduction

Chemistry educators and science education researchers have noted that chemistry is widely perceived by students across many levels of education as being difficult (Johnstone, 2000; McCarthy and Widanski, 2009). This has been particularly the case for nursing students with a non-science background (Davies et al., 2000; Fenton, 2010). The delivery approach and relevance of undergraduate science education for nurses as well as what constitutes an appropriate selection and depth of science content for a nursing curriculum have evoked much debate internationally especially in the areas of chemistry and physics (Fenton, 2010; Jordan et al., 1999; Wilkes and Batts, 1998). Part of the debate has revolved around how to respond to the disproportionate difficulty of science subjects like chemistry compared to other subjects in a nursing course (Caon and Treagust, 1993; Davies et al., 2000; Fenton, 2010; Jordan et al., 1999; Whyte et al., 2011). This has led to some experienced nursing staff, particularly those with non-bioscience degrees, claiming that too much time has been allocated to the teaching of science in nursing courses (Davies et al., 2000). However, classification of nursing activities on the ward (Wilkes, 1992) and an understanding of the skills required to support clinical decision-making (Fenton, 2010) demand some understanding of chemistry. Although nursing chemistry shares some common characteristics with general chemistry, it also has its own distinctive characteristics and this needs to be borne in mind when reading the literature.

Reviewing the literature on prior chemistry experience and academic performance can be a somewhat difficult task because the criteria used for defining these factors are not always specified. Prior chemistry experience could refer to whether a student studied chemistry to year 12 or the grades achieved in year 12 chemistry. Academic performance could refer to achievement based on the results from a particular subject or for all subjects. The impact of prior experience on study outcomes is complicated when non-cognitive factors like motivation, anxiety and self-efficacy are considered, helping to explain to some extent the inconsistent trends reported in the literature for both nursing students studying chemistry and science students studying general chemistry.

One method of assessing academic experience prior to tertiary study is to examine the students' matriculation scores, an overall measure of secondary school performance. Such scores may or may not include chemistry. In Australia, the relationship between matriculation scores and university academic performance is reasonably well established. The university entrance score has been found to be the most significant predictor of academic performance for first-year science students in numerous studies (McKenzie and Schweitzer, 2001; Mills et al., 2009; Zeegers, 2004). However, there are conflicting reports of this link for nursing courses, with some maintaining a correlation with academic performance in first-year bioscience in New Zealand (van Rooyen et al., 2006) and Australia (Whyte et al., 2011), while others report no association (Kershaw, 1989).

Rather than focusing on grades across all high school subjects, student performance in science or more specifically, chemistry, can be examined. A number of nursing studies have considered the relationship between high school science and performance in a tertiary bioscience subject, with some tertiary benefit gained from the study of biology or science at school (McKee, 2002; Potolsky et al., 2003; Whyte et al., 2011). Fenton (2010) demonstrated that nurses who attempted science in senior school found studying science in their nursing course less difficult than for those students who had not studied science at the senior level. However, Mamantov and Wyatt (1978) found no significant dependence on high school chemistry for the performance of a group of nursing students studying chemistry. Prior knowledge was measured by whether or not a previous course in chemistry had been taken but the quality of this knowledge, something rather difficult to assess, was not considered.

In a small study involving motivated students with high ability in science, researchers found that students without high school chemistry could perform as well in college chemistry as their prior knowledge counterparts (Yager et al., 1988). The authors suggest that personal qualities such as motivation, good study habits, perseverance and general ability in mathematics and comprehension may be more important than the pre-mastering of specific concepts.

However, other studies of general chemistry cohorts show a correlation with prior chemistry knowledge (Tai et al., 2006). In one study, prior chemistry knowledge, determined by the use of pre-tests containing prerequisite knowledge for the course, was the best predictor of chemistry achievement ahead of formal reasoning ability and demographic factors (BouJaoude and Giuliano, 1994). In an Australian study, researchers found the failure rate for a first-year university chemistry course was lowest for students with a high school chemistry background: 21% compared with 40% for students with no chemistry background (Schmid et al., 2012; Youl et al., 2006). In a small study in Dublin where prior knowledge was based on performance in chemistry in the final school exam, Seery (2009) found a strong positive correlation with academic performance where the inclusion of prior knowledge increased the variance in academic performance from 17% to 35%. Prior knowledge was the most significant factor in predicting the final exam score. In a study of pharmacy students learning chemistry, researchers noted that almost all prior knowledge tasks correlated with the final grade (Hailikari et al., 2008). In addition, the deeper the level of prior knowledge, the better the grades.

Tai et al. (2006) used an innovative approach to prior knowledge by exploring the connection between academic success in an introductory chemistry course and the prior exposure to specific high school chemistry topics. Time spent on 'stoichiometry' was found to be an important predictor. Interestingly, Schmid et al. (2012) found that students who had studied high school chemistry outperformed others in stoichiometry questions in the final exam.

Some other factors which are known to affect the quality of learning and consequently academic performance for nursing students include the use of metacognitive skills (Zeegers, 2004); the level of student class attendance (McKee, 2002); the capacity of the instructor to give clear explanations for scientific concepts (Kyriacos et al., 2005); the pace of delivery of course materials (Davies et al., 2000; Jordan et al., 1999; Thornton,1997); and the level of reasoning ability (Cavallo et al., 2004).

Numerous strategies have been implemented by universities in an attempt to bridge the background knowledge gap in science courses. Apart from in-semester and summer programs, bridging courses ranging from 3 days to a few weeks have been utilized (Boelen and Kenny, 2009; Penman, 2005; Rutishauser and Stephenson, 1985; Wischusen and Wischusen, 2007; Youl et al., 2006). Two studies for nursing students have considered academic performance in the light of a short bridging course (Penman, 2005; Rutishauser and Stephenson, 1985).

With alarmingly high student failure rates in the first-year Human Bioscience class at the University of South Australia, Penman (2005) implemented an optional 5-day workshop, "Preparing for Sciences", for students without a science background. Survey responses to the course were very positive although a number of students found the content overwhelming. While the small cohort (N=28) and low survey response rate at the end of the semester limit the generalizability of the results, Penman concluded that the course was useful in preparing students for Human Bioscience I and was worthwhile continuing as it provided essential background content.

In a more extensive analysis of the effect of a bridging course, Rutishauser and Stephenson (1985) undertook a 5-year study in the UK to determine the effectiveness of an introductory 3-day course in basic chemistry and physics to assist arts students in transition to the science content of an undergraduate nursing course. Despite some problems associated with the study such as changes to the exam format and an increase in the academic standard of the arts students over the period of the study, the non-science students who had the benefit of attending the introductory course performed notably better. For example, the mid-semester average score increased from 39.1% to 53.6 % and the final exam score increased from 47.3% to 56.4% for these students. It was not reported whether these differences were statistically significant. After the course was introduced there was no significant difference between the arts and science students in marks and failure rates.

This paper reports on a study of the academic performance of first-year nursing students, with varying chemistry backgrounds, in the chemistry component of a unit entitled 'Health Science I'. In order to develop a more complete picture of the relationship between academic performance and chemistry background the study used a mixed method approach, accessing students' conversations about chemistry in addition to their academic achievement in the subject. It differs from the two previous nursing studies reported above in that it focused exclusively on chemistry. The role of physical science in nursing curricula has been open to debate ever since nursing education was incorporated into the university sector in Australia. The results of this study should provide valuable data to enlighten such a discussion. Some pertinent theoretical foundations from learning theories and the conceptual domains in chemistry framed this study.

Theoretical Foundations

Cognitive Load Theory

Cognitive load theory (CLT) has become an influential theory in educational psychology over the last two decades with research confirming its validity and usefulness in implementing effective instructional design (de Jong, 2010; Paas et al., 2010). It relates memory characteristics with instructional effectiveness, taking into account the characteristics of both the information and the learner (van Merriënboer and Sweller, 2005). In order to appreciate how a learner of complex tasks can be overwhelmed by a number of interacting elements (Paas et al., 2010), the theory considers key components of human cognitive architecture: long term memory (LTM) and working memory (WM).

Long-term memory (LTM) is essentially unlimited and stores huge amounts of acquired information as structured schemata. Expertise is built as schemata become more complex as a result of the combination of lower level schemata. Note that an expert does not necessarily possess superior general problem solving skills but rather has access to a complex schema (Sweller et al., 1998; van Merriënboer and Sweller, 2005). The processes by which knowledge can be structured to allow this to occur are central to the theory and inform teaching practice.

Unlike LTM, working memory (WM) is limited in both capacity and duration, particularly for the novice (Paas et al., 2010; van Merriënboer and Sweller, 2005). This 'thinking-holding space' (Johnstone, 1997) is where the learner makes sense of information and solves problems (Reid, 2009). Since highly complex schema will be treated as one element in the WM, limitations apply in particular to new information and as such, the implications for learning cannot be overestimated (Sweller et al., 1998). Cognitive overload occurs when working memory is exceeded (de Jong, 2010), leaving learners overwhelmed by the number of elements that must be processed simultaneously (Paas et al., 2010), thus affecting learning (Reid, 2008).

Three sources of cognitive load affecting working memory are considered in this theory. Firstly, *intrinsic cognitive load* is attributed to the inherent complexity of the task. It is dependent on the degree of simultaneous element interactivity, with high levels difficult to understand because of problems in developing cognitive schema (Paas et al., 2010; van Merriënboer and Sweller, 2005). Prior knowledge plays an important role in decreasing intrinsic cognitive load. Secondly, *extraneous cognitive load* results from the interaction of the learner with the instructional environment. Poor pedagogy and irrelevant material divert WM space from schema acquisition. Consequently, instructional design is particularly important when teaching difficult material (van Merriënboer and Sweller, 2005) and where time and cognitive capacity are limited (Paas,1992). The mental effort required to overcome poor instruction or extraneous information is a consequence of extraneous cognitive load. Finally, *germane cognitive load* is produced by the learner's efforts to process, interpret and construct information in an attempt to make meaning and produce schemata. It will be increased by pedagogical techniques that allow for deep knowledge.

Information Processing Model

In an attempt to give direction to chemical education research, Johnstone (1997) developed a model based on cognitive load theory noting that the most important factor in learning is prior knowledge (Johnstone, 2006). Johnstone named his model 'The Information Processing Model (IPM)' and it has been used to explain a number of research findings in science, and more particularly, chemistry education (reviewed in St Clair-Thompson et al., 2010). Johnstone (2006) has demonstrated both its predictive and explanatory power.

There are three key components to the IPM in Figure 1. The working memory (referred to as the working memory space - WMS) and long term memory components are essentially the same as outlined in CLT. The third component is the 'perception filter'. Since it is impossible to attend to all the incoming stimuli, it is filtered by what we already know and understand: prior knowledge, preferences (importance, interest) and beliefs (Johnstone, 1997, 2000). These experiences stored in the LTM act as a feedback loop and interact with the perception filter. The sieving process of an expert chemist and a novice will be very different because of the matrix of information that exists in the LTM.

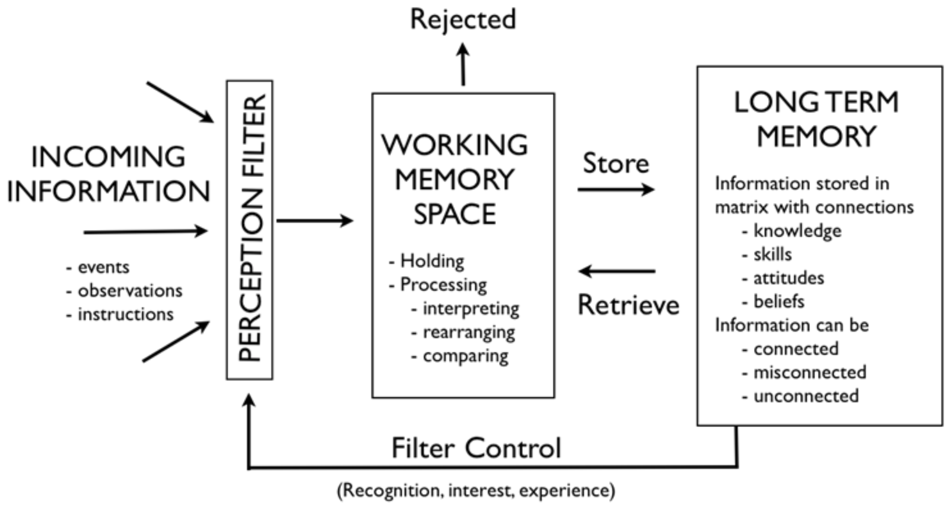

Fig. 1 Information Processing Model (adapted from Johnstone, 2006, and St Claire Thompson et al., 2010).

Conceptual Domains of Chemistry

Another paradigm developed by Johnstone is the notion that chemistry can be seen to manifest itself across three domains: macro (tangible), sub-micro which is abstract (atoms, molecules, ions, structures) and representational (symbols, formulae, equations, mathematical manipulation and graphs) (Johnstone, 2000, 2006). The ‘chemist’s triangle’ is illustrated in Figure 2.

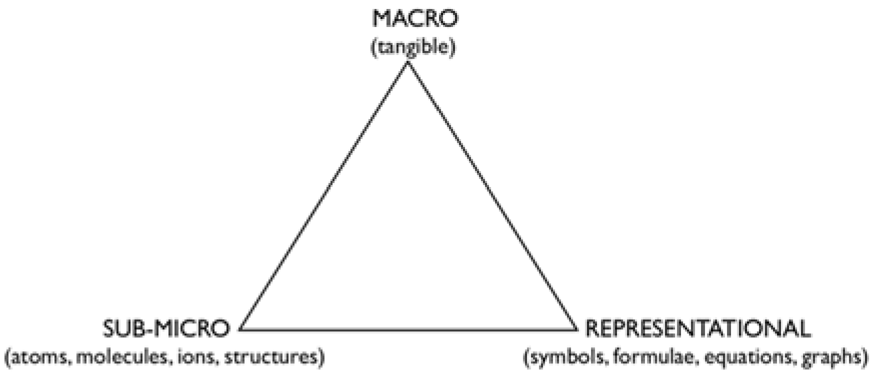

Fig. 2 The three conceptual domains of chemistry known as the chemists’ triangle (Johnstone, 2006).

While the experienced chemist is comfortable working across all three domains simultaneously, this is a difficult task for the beginning student. Research has shown that significant depth of understanding in chemistry requires the simultaneous use of all domains, something which proves to be difficult for the novice student and may result in cognitive overload (Chittleborough and Treagust, 2007; Treagust et al., 2003). The symbolic nature of chemistry poses significant problems for the novice (Chittleborough and Treagust, 2007;

Marais and Jordaan, 2000) as does the unique language which may appear alien (Johnstone and Selepeng, 2001; Logan and Angel, 2011; Ver Beek and Louters, 1991).

Reid (2009) explains that the origin of much of the difficulty experienced in science is that, by its very nature, it is conceptual. In order for concept development to occur, much information must be held at the same time. Johnstone's model demonstrates that intrinsic cognitive load in chemistry is high not only because its inherent difficulty exceeds that of many other learning domains, but because the subject demands that learners change ontological categories during the learning process (de Jong, 2010). Consequently, the novice chemistry learner is particularly prone to cognitive overload.

Cognitive Load Theory, the Information Processing Model and the Conceptual Domains of Chemistry are largely concerned with the cognitive factors involved in learning, including prior chemistry knowledge and academic performance. de Jong (2010) notes that even if intrinsic and extraneous loads are low, learning is not guaranteed because non-cognitive factors can play a role in the learning domain. Johnstone (2006) does not profess to deal with non-cognitive factors like attitude and motivation in the IPM, both of which have been identified as important influences on learning, except for acknowledging their role as part of the perception filter[1]. While non-cognitive factors may be responsible for some of the discrepancies in the studies reported from the literature, the focus of the study reported in this paper is on the cognitive domain.

Course Description and Purpose of the Study

This paper relates to a study of the chemistry experiences of nursing students undertaking a Bachelor of Nursing degree at a College of Higher Education in New South Wales Australia. Health Science I is a core unit taught in the first semester of the degree program made up of approximately 60% chemistry, the remainder being microbiology. The chemistry component was delivered face-to-face in the first part of the semester, consisting of 20 lectures, 7 tutorials, and 4 two-hour laboratory sessions over a period of 7 weeks. Topics covered included basic atomic structure and ion formation; writing chemical formulae; ionic and covalent bonding; basic organic molecules and polarity; solutions including concentration, diffusion and osmosis; acids and bases; equilibrium and buffers; biomolecules and reaction rates. There was no prerequisite for the unit so no prior chemistry knowledge was assumed.

A 3-day chemistry bridging course was offered to students who had not taken chemistry in senior high school. The course was conducted in the week prior to the start of the first semester. It comprised seven 50-minute lectures each followed by a 50-minute tutorial where students worked through exercises related to the preceding lecture material. In addition, an 80-minute laboratory session was conducted on the second and third days. The bridging course focussed primarily on the following concepts at a basic level: atomic structure, chemical formulae, bonding, the periodic table, stoichiometry, the mole, and organic molecules. Concepts from the bridging course were repeated in Health Science I but at a faster presentation pace.

This paper reports on a study which is part of a much larger investigation into the chemistry experiences of first-year nurses. The purpose of this paper is to explore the chemistry experiences of first-year nursing students studying Health Science I by determining if their chemistry conversations and academic performance are related in any way to their chemistry experience prior to their nursing studies. The results of such a study should inform the institution on the efficacy of conducting chemistry bridging programs, guide the nursing faculty in the development of its curriculum, and guide potential nursing students in their choice of subjects in senior high school.

Method

It was considered that the research study demanded a mixed method approach in order to address questions that could not be adequately answered by one method alone. Such an approach can help strengthen inferences, explain and probe nuances in quantitative data, and provide a voice for the diversity of experiences (Creswell and Clark, 2011; Teddlie and Tashakkori, 2003).

The research involved participants voluntarily completing survey items, participating in focus group interviews and subsequent individual interviews. Student identification numbers were used to correlate data from the surveys, academic records and interviews. Identities were then coded.

A survey was administered at the beginning and at the completion of the chemistry component of Health Science I for all consenting students. Demographic data was collected in which students indicated their prior chemistry experience. Based on their prior chemistry experience, students were asked to respond to some questions (listed in Table 5) on the survey administered at the completion of the chemistry component of Health Science I related to their chemistry experience in Health Science I using a 5-point Likert scale. The survey also monitored any changes in students' perceptions of the relevance of chemistry to nursing across the semester using a 5-point Likert scale where '1' represented 'not at all important' and '5' represented 'essential'.

Participants and prior chemistry experience classification

There were 101 students (91% female, 77% <25 years old) participating in the study, representing 93.5% of the eligible cohort. Using survey items, students were classified based on prior chemistry experience (see Table 1).

Table 1 Classification of 101 participants according to prior chemistry experience

Prior chemistry experience	Prior chemistry experience group	Classification of prior chemistry experience groups	Number of students
Senior chemistry	SC	Students who completed chemistry in Years 11 or 12	26
Bridging chemistry	BC	Students who did not complete Year 11 or 12 chemistry but completed the 3-day chemistry bridging course	31
Poor chemistry	PC	Students who did not complete Year 11 or 12 chemistry nor the chemistry bridging course	44

Academic Indicators

Academic performance

There are numerous ways of expressing levels of academic performance. The final chemistry grade for Health Science I was determined using two semester tests (25%), eight laboratory reports (25%), and the final exam (50%). In this unit, laboratory reports were completed before students left the laboratory, which meant they had access to significant support from laboratory assistants if required. Consequently the average marks for this component of the course were quite high and did not necessarily reflect a student's true ability. Further, it has been shown that laboratory marks only weakly correlate with academic performance in tertiary chemistry (Seery, 2009). For this inquiry, academic performance was determined using the semester tests and final exam marks only, using the relative weightings given to each component in the final grade. On the basis of these marks, students were placed into three academic performance groups to enhance analysis: low achievers (<45%), average achievers (45-69%), and high achievers (70+%).

Academic capacity

Eighty-five students (84%) volunteered to complete the Standard Ravens Progressive Matrix test (RPM) outside scheduled class time. It was administered according to the manual guidelines. The RPM consists of sixty "diagrammatic puzzles that exhibit serial change in two dimensions simultaneously" (Raven et al., 1998, p.1) which become progressively more difficult. As such, it measures the capacity to make sense of complexities and to process information while minimising language bias, making it an appropriate instrument for cognitive capacity. The authors claim it provides an index of intellectual capacity but does not purport to measure 'ability', 'intelligence', or 'problem solving ability'. It should be noted that any test of this kind has limitations and provides information on only part of the cognitive spectrum of intellectual factors. RPM was used in this study to act as a control for the effect of capacity on academic performance as it is less influenced by educational background than other measures (Pajares and Kranzler, 1995).

Interview Data

Purposeful sampling strategies were employed to create six focus groups (N=27), two groups for each prior experience category: SC, BC, and PC. The focus groups consisted of 3-5 students. Using information supplied by the surveys, further selection criteria reflecting the range in age, gender, and academic performance (based on the first test) were employed to ensure a level of diversity in each group. Each of the six focus group interviews lasted between 25 and 45 minutes. An interview protocol was created to guide the discussion (see Figure 3). Participants were assigned pseudonyms consistent with their prior chemistry experience group in order to simplify the identification of comments reported. SC student pseudonyms begin with 'S' (eg. Sarina), BC students begin with 'B' (eg. Bella), and PC students begin with 'P' (eg. Paul). Interviews were recorded using video and digital audio files.

Following analysis of group interviews, one member from each focus group was selected for an individual interview to allow for a deeper investigation into issues raised within the group interviews.

Quantitative Data Analysis

A series of statistical analyses were applied using PASW Version 18.0.3. Tests for normality were conducted (Allen and Bennett, 2008) and homogeneity of variance was tested using Levene's test for equality of variances.

Bivariate relationships associated with prior chemistry experience, 'importance of chemistry to nursing' and academic performance were explored using two-tailed Pearson product-moment correlation coefficients, paired samples t-tests, Chi-square and ANOVA followed by post-hoc tests employing Scheffe using an alpha of 0.05. Despite having less statistical power than some other post-hoc alternatives, Scheffe was chosen since some groups were not of similar size and because, being the most cautious of post-hoc tests, it would reduce Type 1 error (Allen and Bennett, 2008; Pallant, 2007). Effect sizes were calculated and since the sample size was relatively small, Cohen's *d* has been reported for t-tests (Thompson, 2008) and eta-squared η^2 for ANOVA (Pallant, 2007).

All Prior Chemistry Experience Groups

1. Why didn't you (or did you) select chemistry in year 11 and 12?
2. Describe your past experiences in science/chemistry.
3. What was your reaction when you realised you would be studying chemistry in this course?
4. How important do you believe chemistry to be in nursing? Why/why not?
5. Do you ever think about how chemistry is relevant to your career? At what times? Does this influence the effort you put into the subject?

Bridging Course Groups only

1. Why did you choose to attend the bridging course?
2. How did attendance at the bridging course help you in Health Science I?
3. How would you rate the contribution of the bridging course to your success in this subject?
4. What was most helpful about attending the bridging course?

PC Groups only

1. Why do you (or do you not) wish you had attended the bridging course?
2. How do you think the bridging course could have helped you?

Fig. 3 Focus group interview protocol for those elements related to prior chemistry experience, achievement in chemistry, and importance of chemistry to nursing.

Qualitative Data Analysis

After applying grounded theory tools to conduct initial coding and memoing on paper, the transcripts were entered into NVivo. Further constant comparative analysis resulted in further amendment and coalescence of codes and categories. This process is to be reported in more detail in another paper. The clustering of codes and categories led to the emergence of three major themes, two of which are of significance for this paper, remembering that the focus in this paper is the comments related to prior chemistry experience in the context of academic performance, relevance of chemistry to nursing, and the nature of chemistry study. The two themes of relevance here are *connectivity*, described as the affinity nursing students have with the curriculum, the profession of nursing, and with people, and *reductivity*, described as the factors that reduce the complexities of chemistry for understanding and the subsequent learning process. The associated categories and codes, their description, and interview evidence are given in Table 2.

The reliability of the code set was enhanced by inviting a chemistry educator with experience in teaching the Health Science I unit, to apply the coding frame to randomly-selected focus group transcripts. A few codes required clarification (e.g. the nature of chemistry) and an additional code, 'effort to learn', was suggested which was subsequently adopted. The overall findings from the interviews were compared with the quantitative findings and the individual responses of interviewees were compared with their self-reported survey data. Any convergence from triangulation increases the confidence of the findings. While such comparative analysis produced some conflict, this does not necessarily indicate invalid findings, but rather "divergence opens windows to better understanding the multi-faceted, complex nature of the phenomenon" (Patton, 2002, p.559). Corroboration of data provided not only confidence in the conclusions drawn but resulted in a more comprehensive picture of the chemistry experiences of first-year nursing students.

Table 2 Qualitative themes, categories, codes, descriptions, and evidence obtained from the interview data

Theme	*Category*	*Code*	*Description*	*Evidence*
Connectivity	Application	Profession	Explores the link between chemistry and the nursing profession.	"I'm happy that we're studying chemistry because I think it's relevant to nursing" (Paul). "I think..there's a lot (of chemistry) that we wouldn't really use" (Sonya).
Reductivity	Nature of chemistry		Chemistry has many unique features, including language that challenges students in their learning. Chemistry is logical and has mathematical components.	" 'Cause I've seen structures and stuff on my boy's book, and I looked at it and I go, this is absolute Greek" (Beth). "I think for me the hardest thing is to get my head around, like, atoms and proteins…and you can't really see type thing" (Phebe).
	Control of learning	Foundation knowledge	Because of the nature of chemistry, a degree of basic knowledge is required for learning.	"I could see I was out of my depth and that I wasn't familiar with it, and didn't have any previous knowledge" (Paula). "You have to start off with the foundation, and I already know kind of where that was goin' to come from" (Samuel).
		Learning Strategies	Strategies-either unique or generic-required or employed to learn chemistry concepts.	"I crammed" (Prue). "Go through this every night.and do it slowly" (Beth). "You have to understand it…it's not something you can just memorise" (Phebe).
		Course structure	Organisational features of Health Science I such as class size, timetabling, pace, lecture notes, and so on that may influence learning.	"I really like the format of the book" (Becky). "So, it's really good, just take it slow. I like slow" (Sofia).
		Study load	The amount of work present in any aspect of the nursing course.	"It took away a lot of hours of study" (Simon). "But it just seems so voluminous in such a short amount of time" (Paula).
		Effort to learn	The degree of application required or employed to learn.	"When other things were going on, I wasn't really likely to put in much effort" (Sarina).
		Work	Paid employment	"I had to work as well, so that cut my time down for study" (Bronte).
	Exposition		Clear, logical and meaningful descriptions and explanations are important for understanding chemistry.	"..and it was really good how you explained it" (Brett). "If the other person understands it, then you feel like your job is done" (Sandy).

Results and Discussion

Both quantitative data and interview data help to provide an informative picture of the chemistry experiences of the nursing students in this study. The chemistry experiences relate to the students' studies prior to and during Health Science I.

Academic Performance and Prior Chemistry Experience

A significant Pearson product-moment correlation was found between prior chemistry experience and academic performance, r =.337, p =.001. Similar correlations have been found in other studies (McKee, 2002; Potolsky et al., 2003; Seery, 2009). Academic performance mean scores across the prior chemistry experience groups are reported in Table 3 and show that academic performance increased with increasing prior chemistry experience. This trend was also observed on the two occasions analysis was applied to the first-year chemistry student cohort data at the University of Sydney for students enrolled in Fundamentals of Chemistry 1A (Schmid et al., 2012; Youl et al., 2006).

Table 3 Academic performance statistics based on prior chemistry experience

Cohort		Number of cases	Academic Performance		Maximum & minimum
			Mean	SD	
Total cohort[1]		100	55.63	19.86	9.5 – 92.7
Group	PC	44	46.60	19.49	9.5 – 88.0
	BC	30	54.20	20.58	17.4 – 83.0
	SC	26	66.93	15.00	41.4 – 92.7

[1]While 101 students participated in the study and completed the surveys, only 100 students completed the course by sitting all tests and the final exam.

In order to investigate this relationship further, ANOVA was employed. Results demonstrated that prior chemistry experience did make a difference to academic performance in Health Science I, $F(2,97)$=6.814, p=.002, η^2=0.132. Post hoc analyses using Scheffe showed that significant differences existed between SC and both PC (p =.002, d =1.13) and BC (p =.045, d = 0.70) groups. This supports other research in general chemistry that has shown that students with high school chemistry experience significantly outperformed those without such experience (Seery, 2009). However, despite the BC students having a higher mean than the PC students, the difference in academic performance between BC and PC groups failed to reach significance.

Despite the lack of a statistically significant difference between the performance of PC and BC students, there is other evidence to suggest that the bridging course did indeed play a role in academic performance. Table 4 shows the distribution of students in each of the academic performance groups based on prior chemistry experience. Note that 52.3% of the PC students were in the low academic performance category whereas only 33.3% and 11.5% of the BC and SC students respectively were in the low performance category. It is also interesting to note that the BC students are fairly evenly distributed amongst the three performance groups. A Chi-square test for independence was used to evaluate whether the distribution patterns were significantly different from each other.

The results showed there was a significant difference, $\chi^2(4, N=100)$ =12.49, p =.014, Cramer's V= 0.25.[2] In addition, an inspection of the adjusted residuals in Table 4 indicates three notable cells (i.e. values > |2|) (Acton and Miller, 2009). PC students are more likely to be in the lowest academic performance group, with SC students less likely. Also, PC students are less likely to be found in the high academic performance group. These figures add some weight to the assertion that the bridging course did contribute to improved academic performance. The results are somewhat consistent with those reported in the University of Sydney bridging course study which compared grade distribution in the various prior chemistry experience groups and found that the proportion of higher grades in the senior and bridging course groups was higher than those with no prior experience (Schmid et al., 2012), although this was not confirmed statistically.

Table 4 Cross-tabulation of academic performance and prior chemistry experience groups[c]

	PC	BC	SC	Total
Low[a]	23 (52.3%)[b]	10 (33.3%)	3 (11.5%)	36
Adjusted residual	3.0	-0.4	-3.0	
Average[a]	12 (27.3%)	9 (30.0%)	11 (42.3%)	32
Adjusted residual	-0.9	-0.3	1.3	
High[a]	9 (20.5%)	11 (36.7%)	12 (46.2%)	32
Adjusted residual	-2.2	0.7	1.8	
Total	44	30	26	100

a. Low = <45%, Average = 45-69%, High = 70+%

b. Values in brackets indicate the percentage of students from the prior chemistry experience group.

c. The assumption of 'minimum expected cell frequency' was not violated, since no cells had an expected count less than 5 (minimum expected count 8.32).

It could be possible that SC students outperformed the other groups because of superior reasoning ability or cognitive capacity. A small correlation was found between Raven's Progressive Matrix (RPM) scores and prior chemistry experience, r =.222, p =.041. However, when ANOVA was used to compare prior chemistry experience groups for RPM scores, it failed to reach significance, $F(2,82)=2.644$, p =.077, adding support to the idea that the difference in academic performance could be attributed to prior chemistry experience rather than the hypothesised higher cognitive capacity of the SC students. Using correlation analysis, Seery (2009) also found that prior chemistry experience rather than general aptitude correlated most strongly with year 1 test scores.

Table 5 Final questionnaire feedback based on prior chemistry experience

Prior chemistry experience	*N*	Survey items completed in the final chemistry lecture ranked on a 5-point Likert scale (0=*'Not at all'*; 1=*'A little'; 2='A fair amount', 3='Much'; 4='Very much'*)	% of students who rated 'Fair amount' or better
SC	26	To what extent do you think your senior high school chemistry studies helped you understand chemistry in Health Science I?	84%
BC	31	How helpful was the bridging course in introducing chemistry knowledge?	87.1%
PC	44	To what extent do you think the bridging course could have helped you with chemistry in Health Science I?	66.7%

When SC students were asked at the end of the chemistry component of Health Science I how they would rate their chemistry background coming into the course, 84% felt it was fair or better (see Table 5). Indeed, the more helpful the students found their senior chemistry experience, the better the academic performance, r =.599, p =.002. It would appear, then, that the prior chemistry experience of the SC students contributed to higher academic performance, suggesting that the quality of prior knowledge does make a difference (Hailikari and Nevgi, 2009). When Samuel was presented with the findings displayed in Table 3 and asked to comment on the difference between the SC and BC results, he offered the following explanation:

Samuel: It'd say it is less the actual information and … knowledge, and more the way of incorporating the knowledge. Like, actually thinking about it analytically,

> symbolically and building those kind of ways of thinking … you know being scientifically literate and actually being able to think about things in that kind of abstract, analytical kind of way. So you build that over several years or even more. It's not just something you can learn in a couple of days. (*Individual Interview*)

Brett indicated during his individual interview that SC students would be building on existing knowledge and skills, whereas PC students were "starting fresh – it's hard". Interestingly, the PC students were rather tentative about the potential value of a bridging course for boosting their academic performance as only 66.7% felt it would have helped them a fair amount or better (Table 5). However, Brett was somewhat surprised that BC students did not have a significantly higher mean than the PC students because:

> *Brett*: [the bridging course] gave you the knowledge that you needed for the first half of the semester, and it was just in 3 days, so it was like, as much as you could pick up, which was surprisingly a lot … it just continuously helped you throughout the semester. (*Individual Interview)*

While 87.1% of the BC students found the knowledge gained from the bridging course helpful as an introduction to chemistry for Health Science I (Table 5), the SC students are more likely to have gained higher levels of procedural knowledge as suggested by Samuel. Of the four levels of chemistry knowledge identified by Hailikari and Nevgi (2009), the ability to apply knowledge (the highest level) was shown to be the only type of prior knowledge to relate positively to the final grade in a general chemistry class.

In order to investigate further the role cognitive capacity may play in the correlation between prior chemistry experience and academic performance, students were placed in three groups based on RPM scores. Pearson product-moment correlations were then conducted for each RPM group between prior chemistry experience and academic performance (see Table 6). What is interesting is that the only statistically significant correlation occurred in the low RPM group. For students with lower cognitive capacity, higher academic performances were more likely to be found in students with more chemistry experience. Since there is no significant correlations between prior chemistry experience and performance in the middle and high cognitive capacity groups, it would appear that, as suggested by Cavallo et al. (2004), students with higher cognitive capacity may be better able to overcome their lack of prior knowledge. Since chemistry requires "formal operational reasoning skills" (Van Lanen et al., 2000, p. 769), prior chemistry experience appears to be a more critical factor for those students with less capacity.

Table 6 Pearson product-moment correlations between prior chemistry experience and academic performance based on Ravens Progressive Matrix groups (N=84)

RPM group	*N*	Academic Performance mean (*SD*)	Correlations between PCE and AP	
			r	*p*
< 47	28	49.30 (18.45)	.413	.029
47 – 50	26	58.44 (18.80)	.135	.510
51 +	30	66.75 (16.35)	.280	.134

NB: Post hoc tests with Scheffe revealed a statistically significant difference in academic performance between the low (<47) and high (51+) RPM groups only.

Student Conversations about Chemistry Study

During focus group and individual interviews students spoke freely about their chemistry experiences both before and during their studies in Health Science I. Student responses were often shaped by their prior chemistry experience and level of academic achievement. Comments about chemistry study and relevance to academic performance in the 'Reductivity' theme were classified under the following codes: foundation knowledge; the nature of learning chemistry; course structure and pace of presentation; and effort required to learn.

Foundation knowledge

The possession of foundation knowledge was a significant feature of the discussion for all prior chemistry experience focus groups. BC students felt that the bridging course provided them with essential prior knowledge, allowing them to build on concepts more easily, a theme noted in other bridging course research (Boelen and Kenny, 2009; Youl et al., 2006).

> *Bella*: I think if I had actually gone straight just to class that first day not knowing anything, I don't think I would have done half as well as what I would having known it.
> *Beryl*: People who didn't do the bridging course, they never actually had, the information was coming at them, and they never had a base for that information to go on.

Interestingly, these two bridging course attendees were placed in the high achieving group at the end of the semester. In contrast, the PC students felt at a disadvantage for not possessing some basic concepts.

> *Paula*: I could see it was out of my depth and that I wasn't familiar with it, and that I didn't have really, any previous knowledge.
> *Interviewer*: What aspects of [the bridging course] do you think would have helped you?
> *Paula*: Familiarity in advance. Just, so you're prepared. So you get the sort of basic, the basic framework of it all. So then, I'd sort of, got a head start and not be so overwhelmed. …

Prior knowledge proved important even for those SC students with a poor performance in senior high school chemistry.

> *Soraya*: Like, it's surprising how much I remembered from high school as well.
> *Sarina*: You've just got that basic knowledge there that will always be built on.

In terms of cognitive load theory, students with prior knowledge are less likely to experience cognitive overload for three reasons: they are able to chunk incoming information; the information anchored in the long-term memory (LTM) allows the filter (as outlined in the Information Processing Model) to select relevant information more efficiently; and more meaningful links to information in the LTM can be created (El-Farargy, 2009; Reid, 2008). Consequently, the working memory has more space to process because it is has less information to hold. For the novice, the working memory is limited because it is busy holding information, much of which may be irrelevant. Further, it is difficult for the learner to find a "connection on which to attach the new knowledge", making it not only challenging to learn but "impossible to retrieve" (Johnstone, 1997, p. 265). Since "conceptual understanding is dependent on the way ideas are linked to each other in meaningful patterns" (Reid, 2008, p. 54), the ability of the novice to understand concepts presented in chemistry lectures is therefore compromised, ultimately affecting academic performance because when the working memory is overwhelmed, learning ceases (Reid, 2008).

Some students in the PC group suggested that, while the chemistry experienced in Health Science I provided a good foundation for nursing, the level of content presented went a little beyond what was probably needed. For example, note the comments of Paula and Paige.

> *Paula*: I think the basic concept of what it [chemistry] does is important, but I don't know if the level of chemistry we've done…..is really necessary.
>
> *Paige*: Agreed. Like, I've been working in aged care as well…..and these people are fantastic nurses and know a lot of stuff, and I'm like, does any of this look familiar to you? And they're like, what is that?...

While statements of this nature are sometimes precipitated when cognitive overload and/or low achievement is experienced, the statements still present a challenge to chemistry educators assisting in the preparation of nurses for the nursing profession.

The nature of learning chemistry

Several aspects of the nature of learning chemistry and its relationship with academic performance became apparent during interviews. The cumulative nature of concept building in the subject, the unique language, the various domains of operation outlined in Johnstone's model (2006) and the logical nature of chemistry are features of student comments considered in the following discussion.

CUMULATIVE CONCEPT DEVELOPMENT

Having prior knowledge meant that students had the foundation on which to build more challenging concepts, a particularly important aspect of the nature of learning chemistry. There is no doubt that students from all prior knowledge groups recognised that knowledge in chemistry is conceptual, sequential, and cumulative (El-Farargy, 2010; Hailikari and Nevgi, 2009).

> *Paul*: Like, chemistry it seems to build progressively, and then anatomy, it's just like so much stuff that doesn't seem related, I mean obviously it's all related but, yeh, it seems worse, [chemistry is] kind of progressive.
>
> *Prue*: But, yeh, chemistry, it's, you've just got to get the main concepts of it and how this flows on to that, that equals that.
>
> *Samuel*: There was definitely a lot of stuff which we didn't cover in Year 11 or 12 but it was just kinda building on top of that, ….

For Sofia, her struggle with chemistry at school related to a lack of basic knowledge and its cumulative structure.

> *Sofia*: … and my teacher, she wasn't very helpful, like I just found it really confusing, everything, and then I forgot the basics, so it was just like a big muddle for me in my head, like all through senior high school.

UNIQUE LANGUAGE

A significant challenge for the science novice is the language, with much of it being described as foreign (Penman, 2005). For some, it essentially equates with learning another language (Logan and Angel, 2011). The lack of acquisition of chemical language can be a significant barrier to learning and solving problems in chemistry (Ver Beek and Louters, 1991). Students from both the PC and BC groups commented on the unique language of chemistry.

> *Beth*: When I first went to the chemistry course, it was like stepping into another world.
> *Beryl*: It is.
> *Beth*: Because I thought it was really going to be like - like another language.
> *Beth*: This is absolute Greek.
> *Brittney*: Terminology, even just the terminology.
> *Beryl*: But when you looked at it and you didn't know what it all meant, it was basically gobbledy-goo, it was quite phenomenal.
> *Pam*: When you were talking, all I was hearing was blah, blah, blah.

The unique language of chemistry requires significant processing, and for the novice, consumes the working memory space leaving little capacity to attend to the concepts presented. Consequently, either little information is passed to the long term memory, or what is passed on is transient (Johnstone and Selepeng, 2001). Learning the language of chemistry is imperative for academic success because complex unfamiliar language consumes much of the working memory space (Johnstone and Selepeng, 2001; Ver Beek and Louters, 1991). In fact, it has been suggested that the difficulties experienced by beginning tertiary chemistry students "appear to be largely precipitated by a lack of chemical language skill rather than by a lack of native reasoning" (Ver Beek and Louters, 1991, p. 391).

THREE CONCEPTUAL DOMAINS OF CHEMISTRY

Aspects of the three conceptual domains of chemistry (Johnstone, 2006) presented earlier in this paper posed problems for those lacking in prior experience. For example, PC students were the only ones to comment on problems with the "submicro" nature of chemistry.

> *Phebe*: I think for me the hardest thing is to get my head around like atoms and proteins and all this stuff and you can't really see type thing, whereas in biology it was a lot more practical.
> *Pam*: Maybe with anatomy, you can see more, you know, the things we're cuttin' up into pieces and looking inside. With chemistry, you can't see it, so you gotta imagine that in your head and it's hard tryin' to imagine it, without actually physically touching it.

The "representational" domain of the model also presented challenges, particularly for those with a poor chemistry background.

> *Paula*: Yeah, once the equations were starting to roll on and things like that, um, just getting an overall view of the content, um, I just thought, oh, I really need to get some extra assistance with this subject.
> *Bronte*: I enjoyed science at school, and I think it's just the formulas that rattled me here.
> *Polly*: The structures, the formulas, you have to memorise and understand.

Research has shown that students' understanding of symbols in a general chemistry class can be more problematic than their understanding of language (Marais and Jordaan, 2000). The importance of working with symbolic representations and modelling abilities for understanding chemistry concepts was demonstrated by Chittleborough and Treagust (2007).

They showed that representations link simultaneously to both the macroscopic and sub-microscopic levels (described as the “unique duality” required in chemistry), and concluded that limited background meant students had limited capacity to both interpret and link, affecting the depth of understanding.

Because of the abstract nature of chemistry, the use of a range of representations is necessary to develop an understanding of the sub-microscopic makeup of matter (Treagust et al., 2003). Research with senior chemistry students has demonstrated that for effective learning based on deep understanding, simultaneous use of the three domains is required (Treagust et al., 2003). For the novice, this represents potential gross overload of the working memory capacity (Johnstone, 2006). Previous exposure to chemistry builds familiarity with the various domains of chemistry, facilitating movement between them and promoting understanding.

THE LOGICAL AND MATHEMATICAL NATURE OF SCIENCE

Previous comments from Pam and Polly illustrate that chemistry is a subject where concepts must be understood. As outlined previously, without a degree of understanding concepts are difficult to learn and academic performance is affected.

> *Phebe*: Like, sociology and psychology, they’re kind of interesting but there’s not like a whole lot of concepts that you have to remember … [but in] chemistry, like, you have to understand, like understand it as well to be able to do the tests.
> *Beryl*: … when you do chemistry, there are so many factors to take in.

The logical and sequential nature of chemistry and its relationship to maths was also discussed by a number of students, including SC students. For the SC students, these were considered positive aspects of the nature of chemistry making it easier to learn.

> *Sandy*: I think it is more close to your basic life things, so you always have a logical explanation why a thing is like this and why things are like they’re meant to be.
> *Bernice*: The way it was for me, like in the bridging course, when you lay it out in front of you, logically, step by step, the process, it’s so much easier. … No, it’s like I need to think about it logically and -
> *Beth*: You are quite right, because it is so logical, it’s like maths, you know.
> *Others*: Yeh.
> *Paul*: I feel like approaching it like studying for maths.

The importance of maths ability in the prediction of academic performance in general chemistry courses has been clearly demonstrated in numerous studies (Lewis and Lewis, 2007; Mamantov and Wyatt, 1978; Tai et al., 2006; Van Lanen et al., 2000; Wagner et al., 2002). Schmid et al. (2012) found that prior chemistry experience played a greater role in maths-based questions in a general chemistry exam, where senior chemistry students out-performed the rest of the cohort. However, these students did just as poorly as the bridging course and poor background students on conceptual questions. While the level of maths required in the chemistry component of Health Science I is relatively low, the interview comments would suggest that in the minds of a number of students, ability in maths still plays a role in academic performance.

> *Interviewer*: How do you think your maths ability affected academic performance?
> *Beth*: Quite a bit. Yeh.
> *Interviewer*: You think so, even though there’s not much maths in [Health Science I]?
> *Beth*: Yes, but it’s the same thought processes, it’s the same. (*Individual Interview*)

The nature of concept construction in science requires a unique learning approach. SC students said very little about the link between the 'nature of learning chemistry' and academic performance, possibly because their experience in the subject meant they were already familiar with the language and the levels on which chemistry processing needs to occur.

Course structure (Pace of presentation)

Adjustment of the pace of presentation to combat perceived difficulty has been reported in previous nursing literature (Jordan et al., 1999). It was not surprising to see that those with little prior knowledge struggled to keep up in Health Science I, contributing to reduced academic performance.

> *Paula*: I think, if I'd had more time to study it I would have been alright, but it just seems so volumous in such a short amount of time. If I'd had more time or if it had been more spread out.
>
> *Pam*: ….. So, I reckon if it was in a longer time period …I reckon people would get better marks …

For Paula, this aspect of her experience was a recurring theme in the individual interview. Reid (2008, p. 56) notes that cognitive overload will occur when "too much has to be thought about *at the same time*." Since the amount of material that can be processed in an allocated time is limited (Johnstone, 1997), modifying the speed or amount of time given in class is one way to help reduce working memory demand for some students (El-Farargy, 2009). In contrast, as explained by Sofia, the SC students enjoyed the "slow" pace of the course.

> *Sofia*: Um, yeh, it's a lot, it's a lot simpler and a lot better, spread out and you explain it a lot better, like slowly, versus just like skimming over it, and some people haven't done chemistry. So, it's really good, just take it slow. I like slow. So that was good.

The BC students noted the difference in pace between the bridging course and Health Science I lectures and seemed relatively happy with the rate at which material was covered, suggesting that the possession of some prior knowledge reduces the demand on working memory allowing students to process more information in the given time period.

Effort to learn

Interview data indicated that having prior chemistry knowledge reduced the study load when a test was imminent.

> *Simon*: It took away a lot of hours of study.
>
> *Soraya*: … it just cut down the study.
>
> *Beth*: If we had not done [the bridging course], we also had to deal with anatomy and you wouldn't have had the time each night to go over it …

Only SC students referred to procrastination when it came to studying for a test. While there were no doubt procrastinators in all prior chemistry groups, it appeared as though the SC students were still able to perform well enough to pass because the transfer of information into the long-term memory, which requires a significant amount of effort (El-Farargy, 2009), is enhanced if a substantial network of interconnected links on which attachment can occur already exists (Johnstone, 2000).

In summary, the responses of the various prior chemistry experience groups varied in their orientation to chemistry. SC students found that the prior chemistry knowledge gained at school gave them the foundation to more easily process new concepts and consequently found the material less difficult to learn than the PC or BC students. In addition, they experienced little difficulty with the mathematical element of the course and moved with apparent ease between the macroscopic, microscopic and symbolic aspects of "the three domains of chemistry" model. As a result, they were able to operate at the procedural level of problem solving, allowing them to achieve at a higher level. BC students were very positive about the role of the bridging course in providing a basic chemistry foundation.

Academic Performance and Importance of Chemistry to Nursing

Students completed a survey item concerned with the importance of chemistry for nursing on the initial and final administration of the survey. As Figure 3 shows, this issue was also addressed in the interviews to help create a more complete picture. The Pearson product-moment correlations between academic performance and initial and final measures of importance of chemistry variables show that the 'importance of chemistry' measure recorded at the beginning of the course gave little indication of final academic performance in Health Science I (r=-.082). However, the correlation strengthened as the semester proceeded and was significant at the final measure (r=.437, p<.001).

As a consequence of this significant correlation at the final measure, one-way ANOVA was conducted to compare perceptions of chemistry importance means for academic performance groups. Post hoc tests with Scheffe showed that the low performance group (M = 3.00, SD = 0.86) felt initially that chemistry was more important for nursing than the average performers (M = 2.44, SD = 0.84), p=.030, d=0.66. There were no significant differences initially between the other groups. However, significant differences emerged for importance by the end of the chemistry component of the course and a discussion of these, along with interview data for importance, follows.

While some students rated the importance of chemistry as '5 - essential' at the beginning of the course,

> Paul: Nah, like I reckon it's pretty relevant to what we're doing … it's good that we're doing it. Yeh, I'm happy that we're studying chemistry because I think it's relevant to nursing.

many students had trouble making a professional connection with chemistry early in the semester.

> Interviewer: Did you ever think during the course that chemistry is really relevant to nursing?
> Bernice: Not when we started learning about it.
> Bella: Not at the start.
> Bronte: Well, I don't really think, well, at the beginning, I couldn't really grasp the concept of why we are doing chemistry for nursing.

However, as noted in the literature, when chemistry is presented in an integrated way to show its relevance to future nursing, student attitudes can change (El-Farargy, 2010; Fenton, 2010; Kyriacos et al., 2005; Logan and Angel, 2011). Focus group participants noted several specific nursing applications of chemistry mentioned throughout the semester: formulas and medications, concentrations, osmotic pressure/tonicity/IV fluids/oedema, urine analysis, pH levels, equilibrium and buffers, pathology, and blood gas levels. As students encountered specific nursing examples during the course, the relevance for many increased.

> Bronte: since we've been doing Anatomy & Physiology more I understand more how important it is - to have chemistry with nursing. The buffers. The pH levels. Yeh, so. Now it's all starting to fit into place.
> Brittney: You understand the chemical side to the body.
> Brett: Yeh, definitely when we started, I couldn't see any point of it. But, now I definitely do.

Despite these comments from Brett, Brittney and Bronte, none actually recorded an increase in relevance reported in the questionnaire from the initial survey to the final survey. Since the focus group interviews were held two weeks after the completion of the final survey, students were possibly making a more reflective assessment of the importance of chemistry to nursing than what was possible in the heat of the moment of having just completed a relatively difficult chemistry topic at the time the final survey was administered. This more reflective stance is further illustrated by a bridging focus group.

> Bernice: No, I was like why do we need chemistry in nursing? I now know why.
> Beth: Oh, it's essential. You have to do chemistry.
> Bella: I think I didn't understand it actually at first. I thought, oh, we need to know a bit of chemistry, but I didn't think it was that involved that we needed to know all that chemistry, but now that I do know it, I felt I can apply that bit there. It wasn't just, we were doing chemistry for no reason.
> Beryl: I just don't see how you can do it [nursing] without it.
> Beth: Nor can I. How can you understand …
> Bernice: Maybe not as much as we learned, but I can see that we need it.
> Beth: But you need to know that to understand buffers and equilibrium and
> Bernice: Yea, true.
> Beth: you just can't learn those things without the basics.

The nuances found in the preceding interchange show a difference in opinion on the degree of relevance of the level of chemistry studied in Health Science I. The strength of the comments is reflected in the ratings given at the final survey by each of the participants: Beth and Beryl '4' and Bella '2', with Bernice indicating a decrease from '3' to '1'. Other students also commented on the lack of relevance, particularly with respect to the depth of some of the chemistry.

> Phebe: … I know it's like background knowledge and that's what you were kind of saying but I was like, aw, realistically, when are we ever going to use this on the ward like at work, like I'm never really actually going to use this … and then like I think that by the time, like once the three years is actually over, how much chemistry are we actually going to remember from the first seven weeks, if that makes sense?
> Paula: I think the basic concept of what it does is important, but I don't know if our level, the level of chemistry that we've done is, that high is really necessary.
> Paige: Agreed. Like, I've been working in aged care as well …and these people are fantastic nurses and know a lot of stuff, and I'm like, does any of this look

familiar to you? And they're like, what is that? Like, general chemistry - I understand that definitely is required, but there's things in there that are really, really full on … and seem unnecessary.

Other research supports Paige's contention that some student nurses struggle with relevance when they speak to good nurses who say chemistry has no bearing on nursing practice (Singh, 1995).

By the end of the semester, ANOVA followed by Scheffe tests showed that low achievers rated the 'importance of chemistry to nursing' at a significantly lower level than both average (p=.023, d=0.53) and high (p<.001, d=1.15) achievers, with no significant difference between the high and average groups (p=.120). This is consistent with the findings of Caon and Treagust (1993) who found the low achieving first-year nursing students more likely to fail to perceive the relevance of science to nursing. In the current study, 36.1% of the low achieving group saw chemistry as slightly useful at best, compared with 12.5% of the average performers and 3.1% of the high achievers. No significant correlation has been found between relevance of science to nursing and academic performance by others (Jordan et al., 1999). Research has shown that motivation to learn science can be influenced by belief in the relevance of the science studied to one's career (Glynn et al., 2007).

The relevance of bioscience (of which chemistry is a component) to nursing has been widely reported in the literature. While some studies indicate students struggle to see its relevance (Thornton, 1997), it appears the majority of nursing students recognise at least some value in the inclusion of bioscience in the course (Davies et al., 2000; Jordan et al., 1999). In fact, a number of studies have found registered nurses recognise the importance of chemistry to clinical practice, providing knowledge and skills that allow them to increase their competency as patient advocates, particularly in rural settings (Fenton, 2010; Kyriacos et al., 2005; Logan and Angel, 2011). Furthermore, nursing students are less successful academically in subjects like bioscience when it is perceived to be less relevant to nursing (Caon and Treagust, 1993). The link between relevance, effort and academic performance was noted by Soraya.

Soraya: At school … a lot of it [chemistry] just didn't make sense to me either, like it seemed really irrelevant to learn a lot of the stuff too, which annoyed me, so it means I didn't want to learn it.

The relative importance of chemistry to nursing can influence the amount of effort put into study.

Interviewer: So, recognizing that [chemistry] is important …, does that influence you to put in more effort?
Brittney, Brett, Bree: Yes, yes (*enthusiastically*)
Brett: If I could see that it was directly related to nursing, I'd sort of keep it more in my brain. I'd be like, like it wouldn't be as superficial, I'd be like, I need to remember this point and I'd highlight that one and actually remember that point, yeh, remember that part. (*Individual Interview*)

In fact, Brett revealed in individual interview that for him, 'application to nursing' was a very significant category in relation to academic performance. It also became apparent that the motivation to study for some students came from the fear of incompetence resulting from lack of chemistry knowledge.

Bree: I think a pass is good as well, except, I, I don't want to be in a hospital situation, and be like, 'crap! I should have studied chemistry and like you don't know - and if you don't know things, you can kill someone. That's what was driving me.

Bronte: the chemical imbalance on the haematology or something. You'd be like, I should have paid more attention in class.

Pierce: I thought it was kind of important. Cause, like, it is kind of like, even though the doctors give prescriptions, you got to get the amounts right and stuff. And if you give the wrong amount you can kill someone or not help someone …

Whilst it is true that perceived relevance of chemistry to nursing can impact 'effort to learn' and consequently academic performance, it may also be true that students will rate subjects which they find difficult and for which they demonstrate a low level of academic performance as low on the 'importance to nursing' scale. That is, the direction of the relationship could be reversed. For some students, poor past academic performance may diminish motivation to learn which results in less effort, leading to the belief that there is little relevance in what is being studied. For example, when Paige experienced difficulty and frustration in a tutorial, her response was to question the relevance of the material.

Paige: … And then I went to the first tutorial and it was really frustrating and lots of crying and screaming on the phone, "This is ridiculous. Why are we doing all this chemistry?" like, at my mum, and it's ridiculous.

When considering the 'importance of the study of chemistry to nursing', paired-samples t-tests indicated there was a significant decrease for the total cohort (d=0.31) and for the low achiever group (d=1.20) over the semester. In contrast, the increase reported by the average and high performers failed to reach statistical significance. This indicated that the large decrease in the low performance group was responsible for the decrease noted for the total cohort. A similar analysis has not been conducted in other studies using nursing cohorts, and results from general chemistry studies are somewhat conflicting. In one study, similar comparisons based on performance groups using task value for chemistry students showed a decrease for all students, with the low group experiencing the greatest decrease (d=0.76) (Zusho et al., 2003). However, high performers showed an increase in 'relevance of learning chemistry to personal goals' in another study, possibly because enrolment in this class was connected to future career goals (Obrentz, 2011).

Pearson product-moment correlations failed to show any significant relationship between prior chemistry experience and importance of chemistry to nursing. Paired samples t-tests also showed that the small changes in this perception of importance over time failed to reach significance. Since the bridging course was designed to introduce basic chemistry concepts using everyday analogies with little emphasis on the nursing context, it was not surprising to find no change in perception of 'importance' after attending the bridging course. Beth, however, was an exception to this trend (going from '2' to '4') and was asked about her quantitative responses during her individual interview.

Beth: Because in the bridging course, you could see the application by what we were learning. So, of course the application would have risen, unless you weren't paying attention … The chem. we were learning, surely you saw the connection with nursing. (*Individual Interview*)

Summary and Conclusion

The purpose of this study was to determine how academic performance in a Health Science unit might be related to prior chemistry experience and how students from different chemistry backgrounds describe their chemistry learning experiences. The research presented here confirms that there are academic benefits associated with nursing students having studied chemistry to senior high school level. There was some evidence that prior chemistry experience offered the greater academic benefit to students presenting with a lower cognitive capacity, suggesting that higher cognitive capacity has the potential to offset any disadvantage related to prior chemistry experience. However, there was an obvious benefit associated with a long-term exposure to chemistry study. While a 3-day chemistry bridging course provided exposure to basic chemistry concepts and offered some academic benefit in Health Science I for students who had not studied chemistry at senior high school, it is difficult, as Samuel observed in interview, to be enculturated into chemical thinking over such a short period. Learning to speak the language of chemistry, think in sub-microscopic terms and think mathematically in a chemistry context all demand time. For this reason staff from our department actively encourage high school students who are thinking of a nursing career to study senior level chemistry. The research data presented here provides strong evidence for this kind of promotion on careers days. While our nursing faculty are keen to remind us that our role is to assist in the preparation of nurses and not chemists, they recognize that there are benefits in encouraging high school students to study chemistry as a preparation for nursing.

All prior chemistry experience groups in interview commented on the importance of basic chemistry as a foundation preparation for Health Science I and commented favourably on the logical structure of chemistry as a discipline for learning. However, some differences between the groups emerged. The PC group particularly found the pace of presentation too fast and struggled with the sub-microscopic representations of matter. The PC and BC groups commented on the language skills required for understanding chemistry and the difficulties they experienced working with chemical formulae and simple mathematical equations. It appeared that the SC group was already sufficiently familiar with chemical language, formulae, and the pertinent mathematical equations as they saw no need to pass comment on these aspects. Only the SC students mentioned that they could cope with some procrastination in study habits and still handle the course satisfactorily.

As far as ‘importance of chemistry to nursing’ is concerned no significant differences were detected across prior chemistry experience groups. However, this was not the case for academic performance groups. There was a significant decrease in the recorded level of ‘importance of chemistry to nursing’ for the low academic performance group during the semester and by the end of the chemistry component of Health Science I, the scores of ‘importance’ for the low achievement group were significantly lower than that recorded by the average and high achievement groups. This was in spite of the fact that the ‘importance’ score for the low achievement group was significantly greater than that for the average achievement group at the beginning of the semester. Paige’s experience in aged-care nursing did not encourage a positive view of chemistry in nursing, particularly when competent professionals in the workplace had never studied chemistry before. It would seem that low achievers become less optimistic about the relevance of challenging aspects of their studies such as chemistry as the course proceeds.

This study contributes significantly to the literature on the role of the physical sciences in nursing by its examination of chemistry experiences *across* a semester of work in a health science unit both quantitatively and qualitatively. One of the challenges presented in the research is that related to the content of chemistry. While a number of the students could see how the chemistry content was relevant to nursing, some, particularly the PC group, questioned whether the depth of the chemistry presented was necessary. This is an important topic requiring further research. For example, a nursing colleague has questioned whether we need to introduce students to the logarithmic character of p*H*. As chemists we thought this was central to the discussion but our colleague felt that all the students needed to know was that p*H* was a measure of acidity and values greater than 7 indicated basic solutions, values less than 7 indicated acidic solutions, and a value of 7 indicated neutrality. The extent to which nursing chemistry needs to be different to first-year general chemistry requires on-going attention in our view. Significantly, changing the content of nursing chemistry along these lines could likely change the relationship between prior chemistry experience and academic performance and the ways students describe their chemistry experience. These are issues which will need to be examined in future research.

Notes

1. More detailed information on non-cognitive factors will feature in another paper
2. When using 3 categories, Pallant (2007) suggests that a Cramer's *V* of 0.21 represents a medium effect size.

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