'Teach Me Chemistry Like a Ladder and Make it Real' – Barriers and Motivations Students Face in Learning Chemistry for Bioscience

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Abstract

Students enrolled in the Bachelor of Nursing program come with diverse academic abilities, age, language skills and experience. Many enrol without any prior knowledge of the supporting sciences including chemistry. Moreover, whilst some do possess such prior knowledge, they may have had a substantial break since they last studied chemistry. This paper draws from surveys and interviews conducted to investigate students' prior knowledge of chemistry and experiences around learning. These were first year students enrolled in a core unit of anatomy and physiology for which, albeit implicitly some prior knowledge of chemistry is assumed. It explores barriers and motivations to learning chemistry and offers insights into what students need in order to gain a mastery of the foundational chemical principles that underlie anatomy and physiology.

This research is of considerable importance given that the teaching of anatomy and physiology relies heavily on foundation-level chemistry knowledge. It is of great significance if students can be better supported in the successful learning, retention and completion of their nursing studies.

Insights reveal that problems stem from various factors including length of time since their last chemistry studies, language difficulties, students' interests and motivations in the subject, pace and structure of sessions, relevance of information and the students' ability to manage the amount of content. This informs future practice suggesting that it is important to scaffold the learning for all students in a structured and relevant manner. Additionally, it supports the development and provision of resources to support students transitioning into higher education from diverse backgrounds.

Introduction

Core to any course training health professionals is the inclusion of the teaching of human anatomy and physiology which is usually taught in the first year of the degree. Anatomy and physiology rely, in part, upon foundation-level knowledge of chemistry (e.g. chemical symbols; and acids and bases). With this in mind anatomy- and physiology-focussed lessons may be preceded by lectures and classes in basic chemistry either as a separate prerequisite, an optional bridging subject or the first component of an anatomy and physiology unit. Bioscience is an ever burgeoning area embedded in Bachelor of Nursing programs which themselves must encompass an ever increasing body of knowledge if such programs are to meet the career demands of current registered nurses (Benner, Sutphen, Leonard, & Day, 2010; Brown, Henry, Barbera, & Hyslop, 2012). This creates constraints on the amount of

time that can be allocated to foundation-level classes in areas such as chemistry and so commonly such classes do indeed represent a small, albeit significant, early component of anatomy and physiology units. This arrangement may be adequate for students who come to their study with a recently gained and well-developed prior knowledge of basic chemistry. Notably, studies have shown that prior knowledge contributes to future success (Childs & Sheehan, 2009; Seery, 2009). Specifically, students who have prior knowledge of chemistry are more likely to perform better in their examinations (Childs & Sheehan, 2009; Seery, 2009; Wong & Wong, 1999). Having prior knowledge can be considered to be a gradual construction of knowledge for the adult learner by continually building upon models that represent understanding (Seery, 2009). However, what is not known is the extent to which this occurs. Additionally, other possible factors may enable or deter successful performance and true learning. For instance, many students practice rote-learning to pass an examination without understanding the subject matter (Childs & Sheehan, 2009). Also it is said that adult learners, particularly non-science-based adult learners and 'long-term returners' generally perceive chemistry lessons to be irrelevant, boring and difficult (El-Farargy, 2009). Finally, studies have reported that the way chemistry is taught generally results in an information overload in students (El-Farargy, 2009; Thornton, 1997).

Prior reports of teaching approaches pertaining to nursing education have built upon the concepts of prior knowledge and relevance in learning basic sciences which impacts on the meaningful integration of learning with the real world for students (El-Farargy, 2009; Thornton, 1997; Wong & Wong, 1999). For example, Thornton argues that the students' ability to link theoretical concepts with practice and the capacity to apply these principles to the 'real world' impacts upon their learning experience. Thus an awareness of what students might learn in chemistry, and how, could inform future teaching approaches (Thornton, 1997).

In this study we surveyed a cohort of first year students enrolled in either Bachelor of Nursing (BN) or Bachelor of Health Science in Traditional Chinese Medicine (TCM) as to their prior knowledge and experience of learning chemistry and also conducted focus groups to canvas approaches to teaching chemistry that would facilitate learning and avoid information overload. Therefore, this study fits well within the literature regarding the attention given to understanding the elements within the spectrum of knowledge construction that contribute to performance including prior knowledge and content relevance.

The next section briefly explains the philosophical frameworks of this study, which informs the design and methodology.

Research approach

Underpinned by the philosophy of pragmatism (Denscombe, 2003), this study entails a mixed-methods design comprising surveys and focus-groups. Support for mixed-methods highlights the capacity of such an approach to improve accuracy, balance the strengths and weaknesses of each method of analysis (quantitative vs. qualitative) and build a more complete picture (Cresswell, 1998; Denscombe, 2003; Dornyei, 2007).
A paper-based survey was administered to 484 first-year BN and TCM enrolled in the core anatomy and physiology subject for their programs: Health and Homeostasis (H&H). The use of a paper-based survey meant that 97% of those enrolled in H&H participated. The survey encompassed questions regarding:

- prior knowledge and level of chemistry previously studied
- length of time since chemistry was last studied
- performance in students' last chemistry studies, problems dealing with chemistry concepts, and likelihood of using self-study resources. (All using a five point Likert-scale.)
- difficult chemistry topics; and applications of chemistry to the nursing environment. (Using open-ended questions).

Additionally, three focus-groups were conducted. The self-selected students comprised diverse academic backgrounds and work experience. Participants were profiled by age, language backgrounds and prior knowledge of chemistry. The semi-structured discussions expanded and probed the survey insights in further depth. It explored students' prior knowledge of chemistry and experiences around learning H&H. It also investigated barriers and motivations to learning chemistry. It inquired what students needed in order to learn and apply chemistry more effectively. These were linked in with the survey data in terms of understanding the relationships across prior knowledge, relevance and learning chemistry effectively.

Analysis

Statistical analysis on the majority of the survey data was carried out using *SPSSv.15*. The data were subjected to descriptive statistics, significance testing, correlations and binary logistic regressions. Significance thresholds were set at the 95% level. Only statistically significant data have been highlighted.

Recordings, transcripts, detailed notes and co-constructed researcher-participant concept maps were drawn from the focus groups. The data underwent a sequence of data reduction methods including coding, text-grouping and using *Leximancer* to further analyse textual thematic relationships. For ethical reasons, all participants are identified through pseudonyms. The survey and focus groups were conducted with the approval of the Human Research Ethics Committee of the University of Technology, Sydney.

Key Findings

Prior knowledge

Data in Table 1a indicate that one in two first year nursing students had not studied chemistry at the Higher School Certificate (HSC) level (that is at a level sufficient for university entry into a Science course) or higher. Those who did not study HSC level chemistry are also less likely to state that they performed well when they last studied chemistry.

Table 1b shows that the majority of students last experienced some level of chemistry teaching between five to ten years ago. The table also indicates that those who had undertaken chemistry at an HSC level or above are less likely to indicate problems dealing with chemistry concepts (in other words, more likely agree that they had no problems dealing with chemistry concepts). Additionally, the data demonstrates that the proportion of those who indicated that they found difficulties with chemistry concepts were progressively larger as the gap between their last chemistry studies increased. For instance, those who studied chemistry over 10 years ago are significantly more likely to state that they faced difficulties in chemistry compared to one who studied chemistry more recently.

Table 1a: Summary of survey results with regard to prior chemistry study, previous performance in chemistry, problems with chemistry concepts and interest in self-study resources. Results are presented as percentages of the total response.

		Total	Performed well when they last studied chemistry	Would use a self-study resource
			Agree + Strongly Agree	
Studied chemistry at HSC level or above (n = 487)	Yes	54%	42%	64%
	No	46%	***12%**	65%
	*Statistically significant compared to the total levels.			

From the various binary logistic regression models run in SPSS, results show that in comparison to the rest of the cohort, those who had studied chemistry at the HSC level were two and a half times more likely to say that they did not have problems dealing with chemistry concepts (Table 2, right column). Therefore, having studied chemistry at the HSC level contributes significantly to those indicating they have no problems dealing with chemistry concepts. Additionally, those who studied chemistry over 10 years ago were significantly more likely to mention that they had problems with chemistry.

Table 1b: Summary of survey results with regard to years since last studied chemistry and problems with chemistry concepts. Results are presented as percentages of the total response.

		Total	Find dealing with chemical concepts a problem
			Agree + Strongly Agree
Studied chemistry at HSC level or above (n = 487)	Yes	54%	***30%**
	No	46%	57%
Years since last studying chemistry (n = 264)	< 5 years ago	31%	33%
	Over 5 years ago	43%	49%
	Over 10 years ago	26%	***61%**
	Note: Overlap is expected in this set of data, percentages will not add up to 100% *Statistically significant compared to the total levels.		

In reading Table 2, *B* is the dependent coefficient. The coefficient provides the response or relationship between the dependent variable (No problem with chemistry concepts) and the independent variables in the first column from the left of Table 2 (Time since studying chemistry and levels of chemistry studied). A negative figure indicates an opposite relationship. Here, those who studied over 10 years ago are least likely to indicate that they have no problems dealing with chemistry concepts, whereas there is a strong likelihood that those who studied at the HSC level are more likely to indicate that they had no problems with

chemistry concepts. The *Wald* test denotes significance of findings, that is, the higher the Wald figures: the more significant the outputs are. *Sig.* denotes the significance of the findings, that is, the smaller the result, the stronger its significance. '*Constant'* captures factors that cannot yet be quantified. In all tables, the constant is significant (0.000), and hence qualitative insights are needed as these factors are not quantifiable. *Exp (B)* describes the odds ratio and is one of the key aspects of a binary logistics regression analysis. For example, those who studied at the HSC level would be 2.5 times more likely to say that they have no problems with chemistry concepts.

Table 2: Binary logistic regression analysis for mastery of chemistry compared with prior chemistry learning.

Table 2: No problems dealing with chemistry concepts				
	B	Wald	Sig.	Exp (B)
Studied > 10 years ago	**-0.867**	**6.739**	**0.009**	0.420
Studied > 5 years ago	-0.456	3.332	0.068	0.634
Studied post HSC level	0.074	0.07	0.791	1.076
Studied HSC level	0.924	**14.591**	**0.000**	**2.519**
Constant	-1.337	38.464	0.000	0.263

Conversely, Table 1b shows that amongst those who had not studied chemistry at an HSC level many found chemistry difficult. Such difficulties are also skewed towards having a large study gap since their last chemistry studies (61% studied chemistry over 10 years ago). However, the significant implications are that those who have not studied chemistry at an HSC level were three times more likely to indicate that they had problems dealing with chemistry concepts (Table 3) and 1.7 times more likely to state that they did not perform well in their last chemistry studies (Table 4).

Additionally, Table 1a shows that the majority of students, regardless of whether they studied HSC-level chemistry or not, would welcome the use of study resources in their learning of chemistry. In comparing those who would use a self-study resource with those who would not, there were no significant differences between the groups in terms of HSC background nor how recently they last studies chemistry. This could imply that the students' willingness to use a self-study resource may be driven by variables beyond HSC levels and how recently they last studied chemistry.

Table 3: Binary logistic regression analysis for problems chemistry compared with prior chemistry learning. Data is presented as for Table 2

Table 3: Problems with chemistry concepts				
	B	Wald	Sig.	Exp (B)
No HSC or post HSC chem.	1.238	**39.519**	**0.000**	**3.449**
Constant	-0.929	39.569	0.000	0.395

Table 4 Binary logistic regression analysis for perceived poor performance in chemistry compared with prior chemistry learning. Data is presented as for Table 2

Table 4: Performed poorly in chemistry				
	B	Wald	Sig.	Exp (B)
Studied > 10 years ago	0.163	0.373	0.541	1.177
No HSC chemistry	0.571	5.978	0.014	**1.770**
Constant	-1.344	58.504	0.000	0.261

The qualitative data (from the focus groups) indicate that prior knowledge may not always result in positive performance as it is also dependent on the number of years since chemistry was studied (as evidenced by the quantitative data), and how much students engaged with the subject then. Examples are as follows:

> *"I've just got very limited knowledge of chemistry and that's primarily due to having not done chemistry as a specific subject at high school and it's been a number of years since I've been in high school. Also it wasn't sort of thing of interest to me at high school either. (Jimmy)*

> *"I think I have a quite poor level of chemistry knowledge so I've never really done it at all, except for the basic tiny amount of stuff you do in high school because that was so long ago. I think that's why I found that first lecture just completely overwhelming. I was like, oh my God." (Heidi)*

Performance vs. problems

Data in Table 5 suggest that those having problems dealing with chemistry concepts are five times more likely to state that they performed poorly in the last time they studied chemistry. If performance is a priority, this has critical implications for faculty to address as to how they might help students deal with chemistry concepts.

Table 5: Binary logistic regression analysis for perception of performance compared with prior chemistry learning. Data presented as for Table 2

Table 5: Perform poorly in last chemistry studies				
	B	Wald	Sig.	Exp (B)
Problems with chemistry	**1.641**	**39.536**	**0.000**	**5.158**
Studied > 10 years ago	-0.211	0.529	0.467	0.810
No HSC or post HSC chem.	0.218	0.738	0.390	1.243
Constant	-1.844	75.631	0.000	0.158

The data in Table 5 indicate that students' perception of their performance and their acknowledgment of having problems with learning chemistry are strongly correlated. Yet the data from previous tables also demonstrate that the drivers of these relationships can be different. *Performance*, for instance, correlates with the level of prior knowledge (that is, no HSC-, HSC- or post HSC chemistry knowledge) whilst *problems* dealing with concepts significantly correlate with both prior knowledge levels and how long ago the students might have studied chemistry. Therefore, the data suggest that how a student perceives their performance in chemistry is not significantly dependent on how long ago they learnt chemistry but more on the existence of prior knowledge and level of that knowledge.

Chemistry as a 'different language' and NESB students

Students of non-English speaking backgrounds (NESB) who have prior knowledge of chemistry feel confident but still admit having difficulties with chemistry.

> *"I used to be a chemistry tutor in my home country, and I worked in a pharma[ceutical] company. But here, it's a different language... I need to re-learn everything in English. I work harder and I have to write more notes and summaries to learn better. Yeah, I need to translate every class because in my country we use our own language's terms..." (John)*

The occurrence of NESB in this study was an incidental finding and is not within the scope of this project. Nevertheless, we felt that it was a point of consideration for future work. Sawir highlights that NESB students entering English-speaking tertiary environments are reliant on their prior knowledge of English as well as the subject matter (Sawir, 2005). Thus, her ideas support the findings here, where coping with problems of interpretation and expression contribute to learning challenges.

Real-life contexts provide relevance to the learning

Any new knowledge often builds on the specific domain of the discipline, and purpose helps a user to focus on the essentials in a sea of information (Visintainer, 1986). The domain of nursing is often described as the '*delivery of care'* (Brixey, Robinson, Turley, & Zhang, 2008; Christine Duffield, et al., 2005; C Duffield, Gardner, & Catling-Paull, 2008; Finfgeld-Connett, 2008; Visintainer, 1986). In the case of health professional students, the data indicates that what is likely to facilitate the learning of chemistry is where lessons are presented in the context of the students' experiences of the real world and/or in how such knowledge aids in the provision of patient care.

> *"Sometimes I use this in my real life. Like, when I clean my kitchen, I use baking powder, things like that." (John)*

> *"Yeah... When we're talking to patients about what's going on and they ask what's this drug for... then we can say this is what happens with the body.... Then the patients feel a little bit comfortable knowing that we've got a good understanding what's going on." (Jimmy)*

This is akin to what has been described as an "appreciation" for the learning where the learning will help the students achieve their future work objectives (Brophy, 1999). In these circumstances it was not surprising that the principal association students made between chemistry and health care was with medication and pharmacology (Figure 1). This includes medication in terms of substances and interactions, and medication orientations around patient care, administration and effects on patients.

Content relevance

Related to the importance of the context of the teaching, the focus group data revealed that if student learning is accompanied by the perception of content relevance, then perceptions of a lack of relevance will devalue any lesson (also: (Knight & Lee, 2001)). Less relevant teaching content is considered to be frustrating and confusing for some. Reichenback suggests that knowledge begins with distinguishing the relevant from the irrelevant (Rechenback, 1968). The ensuing discussion demonstrates the point:

Table 6: Analysis of the factors that contribute to difficulties with chemistry. Pearson correlation shows the relationship in terms of how one variable varies with another variable (extent of variation), but it does not show causality. It shows the relativity and direction of that variation. Negative correlations (or values) describe an inverse relationship, for example, those with chemistry knowledge at the HSC level are less likely to indicate that they face problems dealing with chemistry concepts. Values fall between -1 and 1. As a rule of thumb, a high correlation is depicted by values from 0.5 to 1 or -0.5 to 1.The large sample sizes (n) demonstrate the robustness of the test results*: significant at $p < 0.05$

		HSC chem.	No HSC chem.	Post HSC chem.	Studied > 10 years ago	Studied > 5 years ago
Problems with chemistry concepts	Pearson correlation	-0.29*	0.29*	-0.10*	0.21*	0.12*
	Sample, n	467	467	468	465	452
Performed well at chemistry	Pearson correlation	0.19*	-0.19*	0.14*	-0.06	-0.02
	Sample, n	390	390	391	390	376
Did not perform well at chemistry	Pearson correlation	-0.12*	0.12*	-0.14*	0.04	0.04
	Sample, n	390	390	391	390	376

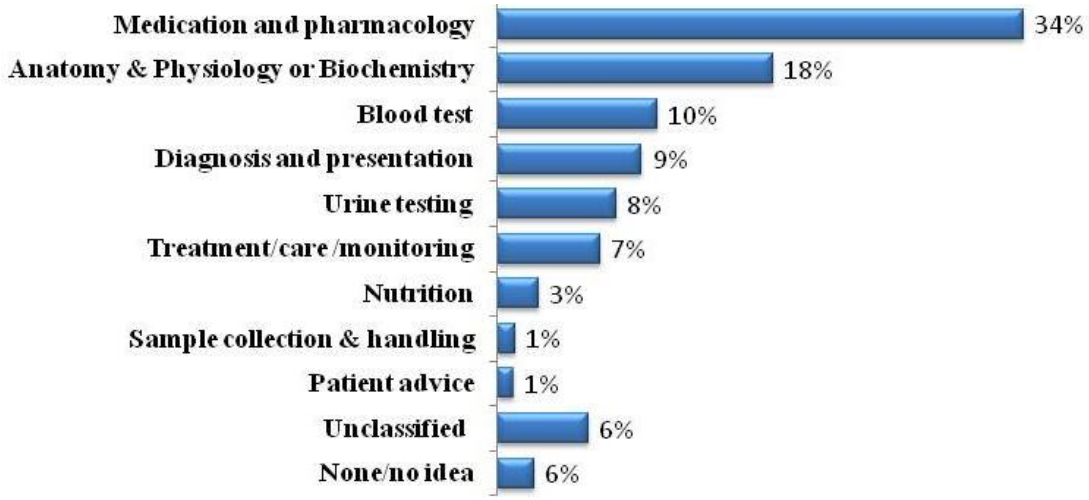

Figure 1: Student-provided examples of where a nurse or health practitioner would use a chemical concept

"We can hardly see the relation between the chemistry that they taught and what we're learning." (Mel)

"Remember the other day in respiratory - she went through all that chemical reaction and then she goes, oh don't worry - it won't be in the exam[ination]. That was confusing - why cover it?" (Anouk)

"They step in and they go oh but don't worry you don't need to know that. Then you just think, well why tell us?" (Jane)

Information disconnect and overload

A concern with chemistry teaching is that it can overload the working memory space in the learner. Overload occurs when learners cannot differentiate important information from irrelevant information (Mancy & Reid, 2004). It can also cause a disconnect between teaching and learning thus inhibiting the latter.

"The chemistry - it's like you said, it's the basis for a lot of the other stuff that goes on. But I didn't think it was really kind of explained in that way. It was just like, bang, here's all this stuff that goes on." (Heidi)

In addition to the volume of content another concern is the pace in which basic chemistry is taught. That is the subject matter is too complex and voluminous to grasp within the short time that is commonly allocated for this. This is exemplified by the following accounts:

"The first lecture which was the basis of chemistry.... But that lecture was just awful. It was so fast. Lots of content. Like if you want us to understand that content just for that first lecture we should spend maybe three or four lectures minimum for really understand all the content that we learnt, that supposedly we learn that day." (Matty)

"... the lecture is three hours long after you've listened to it for three hours you think, what? ... It's just information overload." (Jane II)

"It's just too much." (Mel)

"You can't even listen by the third hour!" (Jane)

This also implies that students prefer chemistry knowledge to be constructed and taught incrementally and built up over time to help them grasp and relate to the content.

"Chemistry is like a ladder. You will go one, two, three so if you jump from the first step to eight, you already don't know anything." (Nettie)

"…. because it'd have to be …. step by step because if we miss the first - or the five first steps we just get lost…..I get lost." (Mia)

Discussion and conclusion

The research aimed to acquire a "snap shot" of students' prior experiences of learning chemistry in order to assess the need for learning support. The data revealed a broad range of experience with regard to prior learning of chemistry and we were able to assess the extent to which prior knowledge of chemistry (and their prior experiences of learning chemistry) influenced students' capacity to master the basic chemistry concepts embedded in their anatomy and physiology lectures and classes. It also purposed to reveal other factors that might drive or hinder student mastery of these concepts. Thus prior knowledge and previously perceived success were strongly linked to a sense of mastery and this is in agreement with the literature. Significantly, it has been demonstrated in Table 5 that students having problems dealing with chemistry concepts (regardless of prior knowledge) are far more likely to perceive themselves as poor performers compared to those who have very little or no prior knowledge but are able to grasp and build on chemistry concepts.

As summed up by Figure 2, these problems stem from various factors including length of time since their last chemistry studies, language difficulties, students' interests and motivations in the subject, pace and structure of sessions, relevance of information and the students' ability to manage the amount of content. The factors that were identified suggest that the observed tertiary model is somewhat curriculum-driven and content-led, rather than learner-orientated.

Limitations identified in the study include the lack of opportunity to cross-sample other institutions to check if the conclusions might traverse beyond particular systems or cultures of teaching. Additionally, focus-group participants were volunteers and may not reflect the general student population. Other useful insights might have also arisen if quantitative data on age and gender were included. This was not possible for the survey data as the survey was conducted anonymously. Finally, the study could have been further enriched by lecture and lab observations by the researchers.

Nevertheless, this study has demonstrated in more depth some elements in addition to prior knowledge that impact any perception of mastery such as the quality and level of prior knowledge, student engagement with knowledge and the length of time since their last studies. The findings also suggest that for NESB students, prior knowledge of chemistry may not be adequate students studying in Australia. This finding is incidental and was not intended as part of the original research inquiry and contributes to new knowledge within this context. This is significant because foreign students make up an increasing proportion of students in Australian tertiary institutions For instance, between 1990 and 2003, foreign

enrolments into Australian tertiary institutions rose from 24,998 to 210,397 (Sawir, 2005). This opens up further opportunities to explore this area in future research.

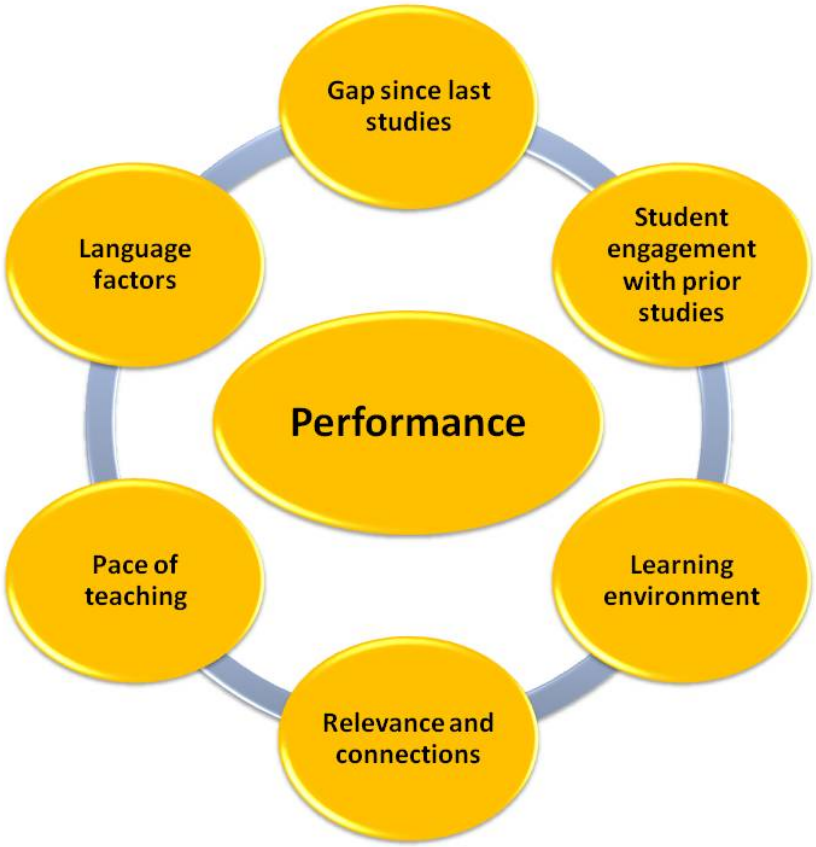

Figure 2: Factors which contribute to a perception of poor performance in chemistry

In conclusion, these insights can inform changes to program design that could contribute to student success. For example, that it is important to scaffold the learning experiences for all students in a structured and relevant manner. The findings indicate that it would be useful to provide bridging material in chemistry (whether a pre-semester program or access to online bridging material during semester) for student nurses to support those with little or no prior knowledge as well as act as a refresher course for those who are less confident in their chemistry knowledge. In teaching practice, in response, we have implemented a pre-test for students to assess their understanding of basic chemistry as well as providing an indicator of what is 'assumed knowledge'. This is intended to help students with the initial stages of gauging their knowledge in chemistry expected at the tertiary levels, and provides students with the opportunities for peer-sharing, engagement and self-directed learning in chemistry.

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