More than Just a Lack of Knowledge: A Discussion of the Potential Hidden-Impact of Poor Pre-enrolment Science Background on Nursing Student Success in Bioscience Subjects

James W. Crane[a,b] and Jenny L. Cox[c]

Corresponding author: James Crane (jcrane@csu.edu.au)
[a]School of Biomedical Science and Centre for Research into Complex Systems, Charles Sturt University, Bathurst NSW 2795, Australia
[b]The University of Queensland, The Queensland Brain Institute, St Lucia, Brisbane QLD 4072, Australia
[c]Faculty of Science, Charles Sturt University, Bathurst NSW 2795, Australia

Abstract

As medical knowledge and technology becomes more complex, twenty-first century nurses are required to possess an advanced understanding of many bioscience concepts. It is now recognised that without this advanced knowledge, nurses will not be sufficiently prepared to deal with the intellectual and technological demands of today, let alone the future. While the importance of bioscience education to nursing practice has been long recognised, nursing students, as a group, have a well documented struggle with science subjects. This struggle has been largely attributed to the lower university entrance scores required for nursing courses and a lack of previous science study. However, as in any complex system, a multitude of factors are likely to be responsible for the difficulty faced by many nursing students in their science studies. In this paper, we argue that a lack of engagement with science early in a student's life can significantly influence student's feelings towards science subjects, the achievement goals that they set themselves, and their interest in learning science. Given the wealth of evidence that high-school students are avoiding science-based subjects, low levels of engagement with science and high-levels of anxiety towards science-based subjects are issues increasingly faced by tertiary science educators. As such, understanding the science background of students, and improving their attitudes and feelings towards science, is a critical first step in helping nursing students learn the science required for their future practice.

'To practice safely and effectively, today's new nurses must understand a range of nursing knowledge and science, from normal and pathological physiology to genomics, pharmacology, biochemical implications of laboratory medicine for the patient's therapies, the physics of gas exchange in the lungs, cell-level transport of oxygen for the acutely ill patient, as well as the human experience of illness and normal growth and development – and much more.' (Benner, Sutphen, Leonard, & Day, 2010, p1)

In 1910, the Flexner report, *On Medical Education in the United States and Canada 1910*, began a transformation that saw scientific knowledge and investigation take a central position in medical education (Duffy, 2011). Building medical education upon a foundation of science produced more knowledgeable practitioners, drove innovation and discoveries in health care, and led to an unprecedented improvement in human health that helped produce a

doubling of life-expectancy during the 20th Century (Frenk et al., 2010). A century later, the 2010 Carnegie Foundation report, *Educating Nurses: A Call for Radical Transformation*, reaffirmed the importance of science in medical education, and more specifically in the education of nurses (Benner et al., 2010). While nursing educators have been debating the value of science in the nursing curriculum (Jordan, 1994; Trnobranski, 1993; Wynne, Brand, & Smith, 1997), advances in medical knowledge and technology have continued unabated. As a result, today's nurses need a "sophisticated understanding" of a range of scientific concepts from anatomy and physiology through to chemistry, physics and genomics to make informed decisions about patient care (Benner et al., 2010). Recently, questions have been raised as to whether we are preparing nursing graduates for the demands of the present, let alone the future (Benner et al., 2010; Frenk et al., 2010). There are also fears that, as nursing-education struggles to keep pace with research- and technology-driven advances, a "practice-education gap" is developing (Benner et al., 2010). Perhaps now more than ever, highly educated nurses, with a comprehensive understanding of science, are required. However, it is well recognised that nursing students, as a group, struggle with science-based subjects. How then can tertiary institutions produce the nursing graduates needed? Clearly, improvements and innovations in the design and delivery of science-based subjects are part of the solution. However, as with any complex system, a host of other factors influence student learning and performance. The aim of this paper is to discuss some of the factors that could influence nursing student's success in bioscience subject that appear to have been largely overlooked. We argue that a significant factor impacting on student success is a lack of prior engagement with, and interest in, science. This lack of engagement/interest may lead to the development of science anxiety, reduced self-efficacy and performance-avoidance achievement goals, all of which will negatively influence student learning and performance in science subjects. By examining some of the potential hidden-impacts of low pre-enrolment science background we hope to help educators design courses and subjects that will stimulate interest in science and produce scientifically-literate nursing graduates.

Nursing students and science

The importance of understanding science, and in particular bioscience, to nursing practice is recognised by both nursing students and practicing nurses. In surveying nurses who had completed a post-registration course that included bioscience, Jordan and Reid (1997) found the majority believed that knowledge of applied physiology was strongly related to proper patient care. In all, 95% of nurses reported that their practice improved as a result of the course (Jordan & Reid, 1997). Similarly, in a survey of pre-registration nurses and practicing nurses in the UK, 92% of respondents indicated that biological science knowledge was important to nursing practice (Clancy, McVicar, & Bird, 2000), and in one New Zealand tertiary institution, 97% of nursing educators and students agreed that bioscience knowledge was essential for effective nursing practice (Friedel & Treagust, 2005). In Sweden, the majority of nurses one year after graduation believed their scientific training was necessary for the delivery high quality health-care and gave them the skills to perform critical analysis and evaluate information (Andersson & Edberg, 2010). Consistent with this view, Logan and Angel (2011) reported that 88% of registered nurses in an Australian study viewed nursing as an applied science (Logan & Angel, 2011). Further, Davis (2010) found the majority of registered nurses believed bioscience to be relevant to practice. Anatomy and physiology were seen as most relevant (76% and 79% of responders, respectively), but microbiology, pharmacology, and biochemistry were also seen as relevant (66%, 64%, and 62% of responders, respectively) (Davis, 2010). However, an earlier study by Caon and Treagust (1993) suggests that student's opinion of the relevance of science to practice varies according

to their performance in science subjects. Seventy percent of students that performed well in their science subjects believed these subjects were relevant to nursing practice, and 73% believed they would help them become better nurses. In contrast, only 57% of students that performed poorly in their science subjects thought these subjects were relevant to nursing practice, and 50% disagreed with the view that these subjects would make them better nurses (Caon & Treagust, 1993). A similar relationship between student's performance and attitudes may account for the findings of Birk et al. (2011). In their study, 29% of students felt that their first bioscience subject was the most valuable to their nursing practice, but by the end of their second session only 16% believed the second bioscience subject to be the most valuable (Birks, Cant, Al-motlaq, & Jones, 2011). One explanation for this shift could be that student's attitudes changed as a function of the grade they received in their first bioscience subject. However, these results indicate that student's attitudes about the value of science are fluid and that when students find science difficult they view it as less valuable to nursing practice.

The fluid nature of nursing student's attitudes towards science is an important consideration given the body of evidence indicating that many students find science subjects difficult. In a study by Caon and Treagust (1993), 90% of low performing students (and 72% of average performing students) believed the science content was too difficult considering their science background. Surprisingly, this view was also shared by 42% of the high performing students (Caon & Treagust, 1993). Further, a survey of nursing students in the UK found the majority viewed bioscience subjects as more difficult than almost all other subjects in their nursing course (Jordan, Davies, & Green, 1999). Nursing students also report spending more time on bioscience subjects than other subjects (Davies, Murphy, & Jordan, 2000; Friedel & Treagust, 2005), that science subjects were a source of anxiety and stress (Andrew et al., 2008; Friedel & Treagust, 2005; Gresty & Cotton, 2003; Nicoll & Butler, 1996), and that their science background was not sufficient to cope with the science subjects (Caon & Treagust, 1993; Friedel & Treagust, 2005; Gresty & Cotton, 2003). These results are consistent with reports that difficulty with science subjects can cause students to withdraw from nursing courses (Andrew et al., 2008; White, Williams, & Green, 1999).

The reasons why nursing students struggle to cope with university-level science subjects are, undoubtedly, numerous. However, some factors have been suggested to predict success in nursing courses and science subjects. Houltram (1996) found that older nursing students were more likely to perform better in their course (Houltram, 1996), and similarly, McCarey et al. (2007) found that older students tended to do better on certain assessment items during their course than younger (< 26 years of age) students. These results possibly reflect a greater motivation and confidence of older students (McCarey, Barr, & Rattray, 2007). Interestingly, both studies found only a weak correlation between entry qualification and academic performance. Consistent with this finding, Ofori (2000) reported that previous biology study did not influence nursing student's success in bioscience subjects (Ofori, 2000). However, in contrast to these reports, a number of studies have found a link between entry qualifications and academic performance in nursing courses. Wong and Wong (1999) reported that high school science grades were a significant predictor of overall performance in a nursing course (Wong & Wong, 1999), and studies by van Rooyen et al. (2006) and Newton et al. (2007) found entry qualification to be a good predictor of performance in bioscience and the nursing course overall (Newton, Smith, Moore, & Magnan, 2007; van Rooyen, Dixon, Dixon, & Wells, 2006). More recently, Whyte et al. (2011) analysed student's results at a regional Australian university and found that entry score was the best predictor of nursing student's success. In addition, previous biology study was found to be a

good predictor of performance in bioscience subjects (Whyte, Madigan, & Drinkwater, 2011). However, it is not surprising that students with a history of academic achievement continue to perform well at university. So, the question remains: how can we help students without a strong academic background develop an understanding of science?

The science background problem

Clearly, some prior knowledge of chemistry, physics and biology is beneficial to students taking first year bioscience subjects. However, this raises a problem, and one that is largely out of the hands of tertiary science educators: most students are not doing science at secondary school. In 2008, Ainley et al. analysed Australian student participation in science, maths and technology subjects in their final year of secondary school (Year 12) from 1976 to 2007. The results demonstrate a steady decline in the percentage of students enrolled in biology, chemistry, and physics subjects over this period. From 1976 to 1991, the percentage of students enrolled in biology-based subjects fell from 55% to 36%, and by 2007 enrolments had fallen to 25%. Enrolments in chemistry and physics were even lower, with only 18% of students enrolled in chemistry and less than 15% enrolled in physics in 2007 (Ainley, Kos, & Nicholas, 2008). These results are consistent with the reported science background of nursing students. For example, Whyte et al. (2011) reported that less than 50% of nursing students had studied biology in high school (Whyte et al., 2011), and nursing students report feeling that their science background was not sufficient to cope with the science subjects (Caon & Treagust, 1993; Friedel & Treagust, 2005; Gresty & Cotton, 2003). It is important to note that falling participation rates in science, technology, engineering and maths (STEM) subjects is being seen worldwide. The OECDs 'Programme for International Student Assessment' (PISA) report of 2006, *Science competencies for tomorrow's world*, highlighted a number of issues of concern, including an overall decrease in the percentage of students taking science subjects in the final years of secondary school; that female students were less likely to enrol in science subjects; and that science teachers lacked training and confidence in teaching science (OECD, 2007). The OECD study also found that the majority of students leave high-school with only a basic level of science and mathematics literacy (OECD, 2007).

A focus of the 2006 PISA study was to determine student's (aged 15 years) attitudes and interest in science (OECD, 2007). The results revealed that the majority (89%) of Australian students felt science is valuable to society, but only 55% believed that science was very relevant to them. While 62% of these students indicated they were interested in learning human biology, interest in learning chemistry and physics was lower (48% and 44%, respectively). However, only 36% of students were interested in the way that scientists design experiments, and only 29% were interested in what was required for scientific explanations. Further, very few students reported engaging with science content outside of school. Of the students surveyed, 16% regularly watched science programs on TV; 10% regularly read science magazines or science articles in newspapers; 11% regularly visited web sites dealing with science topics; and 5% regularly borrowed books about science. When asked about the relevance of science to their future study and careers, just over half (55%) of the students felt science would be important for their future studies, but only 39% said they would like to have a career that involved science and only 34% said they would like to study science after secondary school (OECD, 2007). While we have focused here on the views expressed by Australian students, it should be noted that similar views were expressed by students in many of the fifty participating OECD countries (OECD, 2007).

The results of the Ainley et al. (2008) and the 2006 PISA reports reveal much about the science background of the students entering undergraduate nursing courses in Australia (Ainley et al., 2008; OECD, 2007). It is highly likely that: 1) a high proportion of students will not have studied any science subjects in the last years of high school; 2) many students will not feel confident in their abilities to do science; 3) many students will not have enjoyed learning about science in the past and feel that science is not relevant to them; 4) most students will not be interested in how scientific knowledge develops and evolves; 5) the vast majority of students will not be in the habit of accessing resources about science, regardless of how this information is delivered; and 6) many students are not interested in learning science at university and do not want a career that involves science. In short, a substantial number of students are not confident in their abilities to do science, do not have the desired content knowledge, and will not be interested in developing and expanding their understanding of science.

The potential hidden-impacts of poor pre-enrolment science background

The attitudes that students take into their nursing course will influence the relationship and approach that they take to their undergraduate science subjects. The majority of students will commence their degrees with little interest in science; lacking confidence in their abilities to do science; and having made conscious decisions to avoid science-based subjects in the past. Therefore, it is not surprising that many students feel anxious about the science subjects they are required to complete and are focused on simply 'surviving'. Unfortunately, both the anxiety students feel and the 'survival' goal they adopt could have a detrimental effect on their performance in science subjects.

Anxiety
Over the last 20 years, there has been growing recognition that many students experience anxiety when exposed to scientists, scientific concepts and tasks (Mallow, 1991). A number of factors are thought to contribute to the development of this 'science-anxiety' including: previous bad experiences with learning science; negative messages about science during school years; exposure to school science teachers that are themselves anxious about science and their science abilities; a lack of science role models; and the prevalence of stereotypes in popular culture of scientists being male, geeky, and boring. While female students consistently score higher on science-anxiety surveys, the presence of more general, non-specific anxiety appears to be the greatest predictor of science anxiety (Mallow, 2006; Udo, Ramsey, & Mallow, 2001; Udo, Ramsey, & Mallow, 2004). It has been suggested that students with science-anxiety are more likely to become frustrated with science subjects, and to develop a lack of confidence in their abilities to learn science and do well in science subjects. These feelings can culminate in students developing a general dislike for learning science, a lack of engagement with anything involving science, and in lower grades (Chiarelott & Czerniak, 1987). However, while the impact of science-anxiety on student performance is still being determined, the influence of other forms of anxiety (e.g. test anxiety) on academic performance has been more extensively studied.

Test-anxiety was initially thought to simply affect a student's performance during examinations. However, it is now recognised that this anxiety can negatively affect the acquisition of new knowledge and concepts (i.e. the encoding of information); how a student studies and prepares for assessment items (i.e. the storage of information); as well as their recall of information during exams (i.e. the retrieval of information) (Cassady, 2004a). Naveh-Benjamin et al. (1987) found that a sub-group of students with high test anxiety had

trouble processing and organising the course material, and this poor organisation was correlated with lower academic performance. They proposed that reduced exam performance was not simply a problem of impaired recall of information, but also related to anxiety-induced impairments in the processing, acquisition and consolidation of new information (Naveh-Benjamin, Mckeachie, & Lin, 1987). Similarly, students with high test anxiety were found to have poor study habits and to use less effective study techniques (e.g. repetitive reading and memorisation). These habits and study techniques are likely to inhibit a student's ability to acquire new knowledge and understand new concepts, and thus, impair their ability to learn and consolidate new information (Cassady, 2004b; McKeachie, 1984). Students with high test-anxiety are also more likely to credit their poor performance to internal factors (e.g. low intelligence) or other factors beyond their control (e.g. the difficulty of the material or the quality of the teaching) (Cassady, 2004b). Consistent with this, anxious students were also more likely to try to make lecturers feel guilty about the difficulty of the subject and its assessment items (McKeachie, 1984). Whether science-anxiety similarly impacts students learning and performance is yet to be determined, but it is safe to assume that students that are anxious about studying science will experience similar impairments in their ability to learn, consolidate, and recall new information and concepts.

Interest

The 2006 PISA report reveals that many high-school students have not enjoyed learning about science in the past and are not interested in learning about science in the future (OECD, 2007). The impact of a lack of interest in science should not be underestimated. Hidi (1990) has argued that it is interest that determines what we choose to process and the persistence we display in processing this information (Hidi, 1990). Interest drives people to explore their environment and learn new things. It drives an individual's intrinsic motivation to learn, and to expand their knowledge, skills and experiences (Silvia, 2008). Students that are interested in a subject study more and persist in trying to understand for longer (Silvia, 2008). However, given that many students lack confidence in their abilities to learn science (Caon & Treagust, 1993; Friedel & Treagust, 2005; Gresty & Cotton, 2003) it is not surprising that they lack an interest in science. Indeed, it has been suggested that novelty alone is not sufficient to generate interest – individuals must also feel capable of understanding the information. As Sylvia (2008) argues, 'Finding something understandable is the hinge between interest and confusion.' To stimulate student's interest, teachers need to maximise the novelty and the comprehensibility of the subject (Silvia, 2008).

Self-efficacy

The fact that many nursing students feel they do not have a sufficient background in science is also of concern, as it is now accepted that an individual's views about their ability to master a skill or learn a concept can affect their attempts to develop this mastery (Bandura, 1977; Pajares, 1996; Walker, 2010). Self-efficacy beliefs are derived from an evaluation of previous performance in similar tasks, vicarious experience (seeing others perform the task), verbal persuasion provided by others (e.g. teacher), and the emotional arousal the task provokes (e.g. anxiety or pleasure) (Bandura, 1977). Further, these beliefs evolve as individuals engage in tasks, reflect on the outcomes of this engagement, and use this reflection to construct beliefs about their ability to perform similar tasks in the future (Pajares, 2002). A person's self-efficacy beliefs can influence the emotional reactions they have in response to a given activity and how they perform or meet a challenge (i.e. people tend to engage in activities that they believe themselves capable of mastering and avoid those they view as beyond their capabilities) (Bandura, 1977; Pajares, 2002). Individuals that possess a high self-efficacy are likely to be calmer in the face of challenging tasks and more

likely to engage in self-directed learning. In contrast, low self-efficacy is associated with an overestimation of the difficulty of a task; thoughts that can lead to feelings of stress and anxiety (Pajares, 1996). Consistent with this, science self-efficacy has been reported to predict up to 24% of academic performance in nursing students (Andrew, 1998).

Achievement goals

How a student feels about their ability to cope with science subjects can also influence the goals they set themselves for their studies. According to the achievement goal model there are four distinct achievement goal categories: 1) mastery-approach (focused on obtaining competence or learning as much as possible); 2) mastery-avoidance (focused on avoiding incompetence or not learning less than possible); 3) performance-approach (focused on performing as well, or better, than others); and 4) performance-avoidance (focused on not performing worse than others (Elliot, Murayama, & Pekrun, 2011; Elliot & Murayama, 2008). The influence of mastery-avoidance and performance-approach goals is still to be determined. However, it is clear that mastery-approach goals are associated with positive characteristics and outcomes, and performance-avoidance goals are associated with negative characteristics and outcomes. Students with mastery-approach goals are more likely to have positive views of their ability to cope academically (high self-efficacy), to be more persistent in their attempts to understand, to be willing to engage in difficult activities, more likely to use deeper-level learning strategies, to be intrinsically motivated, and to enjoy learning. These students are also more likely to seek and obtain help and have lower levels of test anxiety (Furner & Gonzalez-DeHass, 2011; Urdan & Schoenfelder, 2006). In contrast, students with performance-avoidance goals are more likely to have low academic self-efficacy, to have poor study habits, to engage in surface level processing of information, to procrastinate, to feel threatened by their studies, to fear failing, and have higher levels of test-anxiety. Students with performance-avoidance goals are less persistent (especially in the face of difficulties), lack intrinsic motivation for their studies, are less likely to seek help, and more likely to engage in self-defeating behaviours (Furner & Gonzalez-DeHass, 2011; Urdan & Schoenfelder, 2006).

Implications for educators

In this paper, we have argued that a lack of science background means more than simply a lack of pre-requisite science knowledge. Rather, students that have become disengaged with science and actively avoided science subjects at secondary school are more likely to experience anxiety related to their tertiary science subjects, and that this science-anxiety could influence all aspects of learning (i.e. acquisition, consolidation and recall of new information). In addition, it can further reduce student's interest in science, lower their self-efficacy for science subjects, and lead students to adopt performance-avoidance goals. Unfortunately, the steady decline in high-school students studying science subjects means that many students entering tertiary education will possess, or be at risk of developing, behaviours and attitudes that will significantly impair their performance in science subjects. Indeed, the literature suggests that many first-year nursing students lack interest in science, have a low self-efficacy related to science subjects, and may experience significant science-anxiety. While the achievement goals held by nursing students do not appear to have been directly investigated, it can be assumed that the combination of science-anxiety, low interest, and low self-efficacy will lead many nursing students to adopt a performance-avoidance goal for their science subjects. In our experience, many first year nursing students exhibit behaviours and attitudes associated with performance-avoidance goals (e.g. poor study habits, surface level processing of information, high test-anxiety, and fear of failure). From our

discussions with colleagues, we are confident that many science educators teaching into nursing courses will also recognise characteristics associated with science-anxiety, low self-efficacy, and performance-avoidance goals in their students.

It is our contention that the wider issue of lack of interest in science needs to be addressed head on by nursing courses. This could be achieved by making the first science subject in nursing (and indeed other allied health) courses focused on introducing (or perhaps re-introducing) students to science. This 'Introduction to Science' subject would focus little on content knowledge. Instead, it would deal with issues such as the true nature of science, the benefits of science to society and allied health professions, the relevance of science to their everyday life, and the value of a scientifically literate population to society. In short, it would begin a conversation with students that directly addresses the important question of "why are we learning this?" As Mallow (1986) recommends, this subject would introduce students to the exploratory nature of science investigation and provide opportunities for students to follow scientific evidence to logical conclusions. It would introduce students to effective ways to study science and to develop self-regulation strategies (e.g. personal goal setting). Group work would predominate – as the best way to learn science is to teach it and students are often more willing to listen to the questions and answers of other students than that the lecturer (Mallow, 1986). However, above all, the subject would be a safe place for students to ask questions, try new things and to fail. Success should be based on satisfactory completion and engagement with the activities and tasks, not performance measures (e.g. grades). Such an environment would promote the development of mastery-approach goals and allow students to explore science again, without the pressure of external expectations. In this environment, lecturers can then provide the right mix of novelty and challenge that will drive the development of an interest in science (Silvia, 2008). An introductory science subject would aim to break down barriers and stereotypes that prevent many students from engaging with science, reduce student's science-anxiety, increase their interest in science, and help students to see the relevance of science.

Of course, in already time-poor nursing courses the introduction of a new subject may not be immediately feasible. So, what can be done now? Firstly, we should raise awareness amongst science and clinical lecturers of the potential impact of science-anxiety on student's attitudes, achievement goals and performance in science subjects. Lecturers should be encouraged to talk openly about these issues with students and to share their own experiences with studying science (i.e. what they found hard and how they overcame it). However, they should also be warned of the potential impact of reflecting any science-anxiety they may have back to students. Further, the use of 'flipped-classroom" models could allow lecturers to use face-to-face sessions to stimulating student interest and break down walls preventing student engagement.

Science-anxiety clinics could be created; similar to those established by Mallow at Loyola University of Chicago. These clinics could be staffed by scientists and counsellors and have three aims: 1) teach the skills required to study and learn science; 2) determine the causes of the student's anxiety and develop strategies for reducing this anxiety; and 3) teaching students relaxation techniques that can be used to desensitise them to anxiety-provoking situations (e.g. science exams) (Mallow, 1986, 2006). Helping these students overcome their science anxiety would be the first step in helping them re-engage with science. However, in the absence of such clinics, science academics and student support services could, at the very least, work collaboratively to create support programs that specifically address the academic and emotional issues students commonly have with science subjects.

Finally, in an attempt to address low science-interest and high science-anxiety nursing students, for the last 18 months we have been conducting "Pre-science Workshops". These two day workshops are offered on a voluntary basis and are conducted 1-2 weeks before the commencement of the student's first science subject. The workshops are run by two science lecturers, are delivered in a relaxed and informal fashion, and are focused on stimulating student's interest in science and reducing their anxiety. While science content is presented, it is used to stimulate discussions about its relevance to their chosen career and other aspects of their life. Sessions on how to study science, to evaluate evidence, to tackle exam questions, and to deal with science-anxiety are conducted. The advantage of these workshops is that they can tackle issues face-to-face just before the students begin their first science subject. The initial evaluations of these workshops indicates that students are more interested in studying science and feel less anxious about their ability to cope with science subjects, both immediately after the workshop and 5 weeks into their first science subject. Further, attendees appear to be more likely to pass not just their first science subject but also subsequent science subjects in their course.

As discussed in this paper, there are a number of factors related to a lack of pre-enrolment science background (beyond simply a lack of content knowledge) that could influence nursing student performance in bioscience subjects. While it is widely acknowledged that nursing students are anxious about science subjects, the root cause of this anxiety and the impact that it has on student learning and performance in science subjects has received little attention. This paper aims to raise awareness of the possible links between reduced rates of science participation in high-schools and the development of science-anxiety. Further, we have argued that science-anxiety could cause students to develop low self-efficacy for science subjects and to adopt achievement goals that place them at risk of poor academic performance. It is hoped that by understanding the science background of nursing students (and how this may influence student performance) nursing educators will be able to reduce science-anxiety, engage more effectively with nursing students and stimulate their interest in science. These interventions may be a key element in the development of scientifically-literate nursing graduates.

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