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The impact of several demographic factors on chemistry laboratory anxiety and self-efficacy in students' first year of university

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Abstract

The transition from high school to tertiary education can be a daunting prospect for students. The prospect of laboratories, an unfamiliar environment, for students, can increase levels of anxiety. Moreover, there is a growing body of evidence that suggests that students' self-efficacy is inversely correlated with students' anxiety. We surveyed students at the start and end of a semester to evaluate levels of anxiety and self-efficacy in relation to several aspects of the chemistry laboratory. Time management and answering assessed questions are the aspects that contribute to high levels of anxiety and low levels of self-efficacy at the start of semester. Students generally reported lower anxiety and higher self-efficacy at the end of the semester about every aspect probed. These results are of interest to any discipline that offers an unfamiliar learning environment for students as aspects such as time management and answering assessed questions are not discipline specific. We investigated the different aspects of anxiety and self-efficacy in relation to various demographic factors.

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Student Success: ***A journal exploring the experiences of students in tertiary education***

Introduction

In the context of an undergraduate chemistry laboratory the way a student chooses to act in the laboratory depends on how they think and feel towards the laboratory (Galloway & Bretz, 2015a). Other studies have linked probing the affective domain with improving students' meaningful learning in the laboratory (DeKorver & Towns, 2015; Galloway & Bretz, 2015b; Galloway, Malakpa, & Bretz, 2015). Understanding areas of the affective domain can be an effective strategy in assisting students to succeed in their undergraduate chemistry laboratory classes and their transition from high school to tertiary education.

In recent work on the use of the "Prepare, Do, Review" model for reducing students' negative feelings towards the chemistry laboratory, the authors highlighted the importance of detailing the factors that contribute towards students' negative feelings about the chemistry laboratory (Spagnoli, Wong, Maisey, & Clemons, 2017). Anxiety was one of the negative feelings specifically mentioned. High anxiety has been found to negatively impact academic success, (Abendroth & Friedman, 1983; Westerback & Primavera, 1992) which could also lead to an increase in other negative feelings. Therefore, knowing what students are anxious about is a good first step in developing tailored interventions to further reduce negative feelings about the chemistry laboratory.

In 1999 Bowen developed the Chemistry Laboratory Anxiety Index (CLAI). The CLAI is an instrument for measuring the anxiety of chemistry students about various aspects of laboratory work. The items in the CLAI were validated using factor analysis. The validated factors of the CLAI are as follows (Bowen, 1999):

- students having adequate time
- working with other students
- working with chemicals
- working with chemical equipment
- recording data.

Aims

The research questions that guided this research are:

1. *a) What are the aspects of chemistry laboratory work that first-year undergraduate students are most anxious about?*
   b) What are the aspects of chemistry laboratory work that first-year undergraduate students have lowest self-efficacy about?

2. *What changes occur in students' chemistry laboratory anxiety (CLA) and chemistry laboratory self-efficacy (CLSE) from the beginning to the end of their first semester?*

3. *What changes are seen between students' CLA and CLSE between the start of semester 1 and the start of semester 2?*

4. *What is the correlation between CLA and CLSE and how does this compare to the known correlation between CLA and general chemistry self-efficacy?*

5. *Are the student characteristics of first language, prior and expected aversiveness, and desired and expected grade, correlated with CLA or CLSE?*

Answering these questions will provide an evidence base for educators wanting to target interventions to address the specific aspects of laboratory work that students are most anxious or least self-efficacious about when they start university. Information about how their CLA and CLSE change with time will provide educators with important information to help them time the implementation of interventions well. Knowing the demographic factors

associated with high CLA and/or lower CLSE will help identify students who may be most in need of the support/intervention of educators and may help educators refine the target audience for interventions.

Methodology

Context of study

There are three chemistry level-one units offered at an Australian university. The physical unit had 190 students enrolled in semester one of 2017 and 70 enrolled in semester two. The synthetic unit had 277 students enrolled in semester one of 2017 and 147 enrolled in semester two. Students can take any of these units in any semester. There is one chemistry unit offered in semester one only, which is for students with no chemistry background. This introductory unit had 318 students enrolled in semester one of 2017. In each unit there are six laboratory sessions spread across alternate weeks of semester and each laboratory is three-hours in duration. For each laboratory there is a pre-laboratory video and quiz for students to complete before they attend the laboratory. In this study, only students that took the synthetic unit completed the survey.

Design of the CLASEQ

To gain a more detailed understanding of the elements that contribute to CLA a questionnaire-survey was developed based on Bowen's instrument. This survey will be referred to in this paper as the Chemistry Laboratory Anxiety and Self-Efficacy Questionnaire (CLASEQ, see Appendix A).

Differences between the CLAI and the CLASEQ

This survey included questions about an additional three possible aspects of chemistry laboratory work that may contribute to CLA. These were: asking for help from a demonstrator, interpreting the data and answering assessed questions. Additionally, questions were added that asked students about their CLSE with respect to each of the eight aspects of the laboratory work that were expected to contribute to CLA. These questions were developed with expert educators in the field and were reviewed by chemists and psychologists with research interests in the field to ensure clarity of meaning and intention for the students involved in the study. Finally, the survey included questions about students' characteristics: their preferred spoken language, their prior experiences of the study of chemistry, their expectations of the current unit, and their desired and expected grades. Demographic questions were asked at the end of the survey to avoid creating a bias (Teclaw, Price, & Osatuke, 2012).

Justification of the differences between the CLAI and the CLASEQ

Grades are important to students (DeKorver & Towns, 2015; Seery, 2017), and therefore an important aspect to explore. This was done by including questions asking students how anxious they were about answering assessed questions in the laboratory and about how well they thought they were able to answer assessed questions in the laboratory. Questions were also added about students' anxiety and self-efficacy about interpreting data. In Bloom's taxonomy interpreting data is a higher level of thinking than recording data (Adams, 2015), therefore, is expected to contribute more to cognitive load. Concern has been expressed over the impact of cognitive overload on students' anxiety and learning in the laboratory (Hubacz Jr, 2004), thus it was of interest to investigate whether students were anxious about this cognitive task. The final question to be added was asking for help from a demonstrator. This was included not only for the benefit of students who may feel anxious about or lack confidence in asking for help but also for the benefit of the laboratory coordinator. If one or more of their

demonstrators were not approachable it would be of concern to the laboratory coordinator who could then assist the demonstrator to develop professionally in this area.

Student characteristics – Prior aversive experiences

While not the only cause, in certain settings an aversive experience can create anxiety about future experiences of a similar nature (Locker, Shapiro, & Liddell, 1996). Anxious people generally expect experiences to be more aversive than less anxious people, but regular experiences can, over time, create more realistic expectations (Arntz, Van Eck, & Heijmans, 1990). Negative prior experiences have also been seen to have a negative impact on students in the affective domain and on their CLSE (DeKorver & Towns, 2015).

Student characteristics – English as a second language students

First-year overseas university students display more indicators of stress than their domestic peers (Burns, 1991). Students who spoke English as a second language (ESL) also lacked confidence in academic participation (Sawir, 2005). Universities around the world market themselves on their global reach and diversity. Therefore, in recent years there have been an increased number of international students enrolled in universities. In 2012, there were 216,392 international students in higher education institutes across Australia (Forbes-Mewett & Sawyer, 2016). In 2013-2014 there were 310,195 non-European Union students enrolled in courses with UK higher education institutes, which was a 3% rise on the previous year (McMahon, 2018). Due to higher tuition fees for international students compared to domestic students, universities have a financial incentive to keep this trend growing. Therefore, academics cannot expect the native language of the host university to be the native language of all their students. In fact, a recent study of an introductory chemistry unit at an Australian university found that 40% of students were from international high schools or transferred from another institution (Clemons, Bucat, & Spagnoli, 2018).

Distribution of surveys

The surveys were distributed to all 277 students that completed a core first year synthetic chemistry unit at the start of semester one in 2017. This was done on two occasions, both at the beginning (N=178 completed surveys) and end (N=133 completed surveys) of semester. The surveys were also distributed at the start of the second semester of 2017, (N=53 completed surveys of 147 students completing the unit). Students were sent an email that included a link to the survey hosted on the Qualtrics website. Sampling at these times allowed for a comparison of self-efficacy and anxiety before and after the potential mastery experiences offered by the laboratory. Ethics approval was granted by the university's human ethics office (reference RA/4/1/9011). Students were informed that by submitting the survey they agreed to participate in the research project, which was completely voluntary.

Data analysis

Results from these online surveys were collected anonymously and statistically analysed using the GraphPad Prism software. Due to the ordinal nature of the data, comparing means was an inappropriate method of determining the significance of observed changes (Pallant, 2013). Instead, a Mann-Whitney U test was used to test for any significant differences between students' anxiety and self-efficacy between different time periods. Spearman's Rho was calculated to analyse the correlation within data sets between anxiety and self-efficacy by laboratory work aspect. A comparison of means and of

medians was used to identify and rank the aspects of laboratory work that caused students the most anxiety to lowest anxiety. This comparison was also used to rank the aspects of laboratory work with respect to student's self-efficacy.

Results and Discussion

1. a) What are the aspects of chemistry laboratory work that first-year undergraduate students are most anxious about?

Students at the start and end of semester one and at the start of semester two in 2017 were most anxious about time, followed by answering assessed questions and interpreting data. Students were less anxious about working with chemicals, working with chemical equipment and recording data and least anxious about working with other students and then asking for help from demonstrators. Monitoring student's perceptions of their demonstrators is a very important aspect to consider. This is highlighted by a recent study where students who feel that their demonstrators are supportive, believed that they learnt more (Wheeler, Maeng, Chiu, & Bell, 2016). For means and standard deviations see Appendix B in the supplementary material. There is an observable trend that students report lower anxiety about the social aspects of laboratory work than about the practical tasks and lower anxiety about the practical tasks than the cognitive tasks. The aspects which students were most anxious about were also the aspects that most directly impact student's grades. This provides further evidence to the growing and unsurprising conclusion that students care mostly about the grades they achieve in their studies. There are studies that report similar results in the fields of chemistry (Austin, Hammond, Barrows, Gould, & Gould, 2018). Moreover, there is a known relationship between student motivation and academic performance in the fields of human anatomy and physiology (Sturges, Maurer, Allen, Gatch, & Shankar, 2016), nutrition and physics (Maurer, Allen, Gatch, Shankar, & Sturges, 2013).

b) What are the aspects of chemistry laboratory work that first-year undergraduate students have lowest self-efficacy about?

The opposite was true for self-efficacy. This is consistent with other studies that have tried to relate chemistry laboratory anxiety with general chemistry self-efficacy (Kurbanoglu & Akim, 2010). Students reported highest self-efficacy about the social aspects of laboratory work (working with other students and asking for help from a demonstrator) than about practical aspects (working with chemicals, working with chemical equipment and recording data). They also report higher self-efficacy about practical aspects than about cognitive aspects (interpreting data, answering assessed questions). Completing the work on time was the aspect of laboratory work that students in each survey had lowest self-efficacy about. Again, means and standard deviations for self-efficacy are available in Appendix B of the supplementary material. The expected inverse correlation between CLA and CLSE (of which no reported measures exist) was clearly visible in this data.

2. What changes occur in students' CLA and CLSE from the beginning to the end of their first semester?

There is a general decrease over the semester for anxiety (Figure 1A) and increase in self-efficacy (Figure 1B) of each aspect. As expected, given the mastery experiences afforded by the laboratory sessions self-efficacy increased, and this increase in self-efficacy was coincidental with a decrease in anxiety. Using Mann-Whitney U analysis it was seen that the increase in self-efficacy for each aspects of laboratory work was significant at the $p \leq 0.001$ level for each aspect.

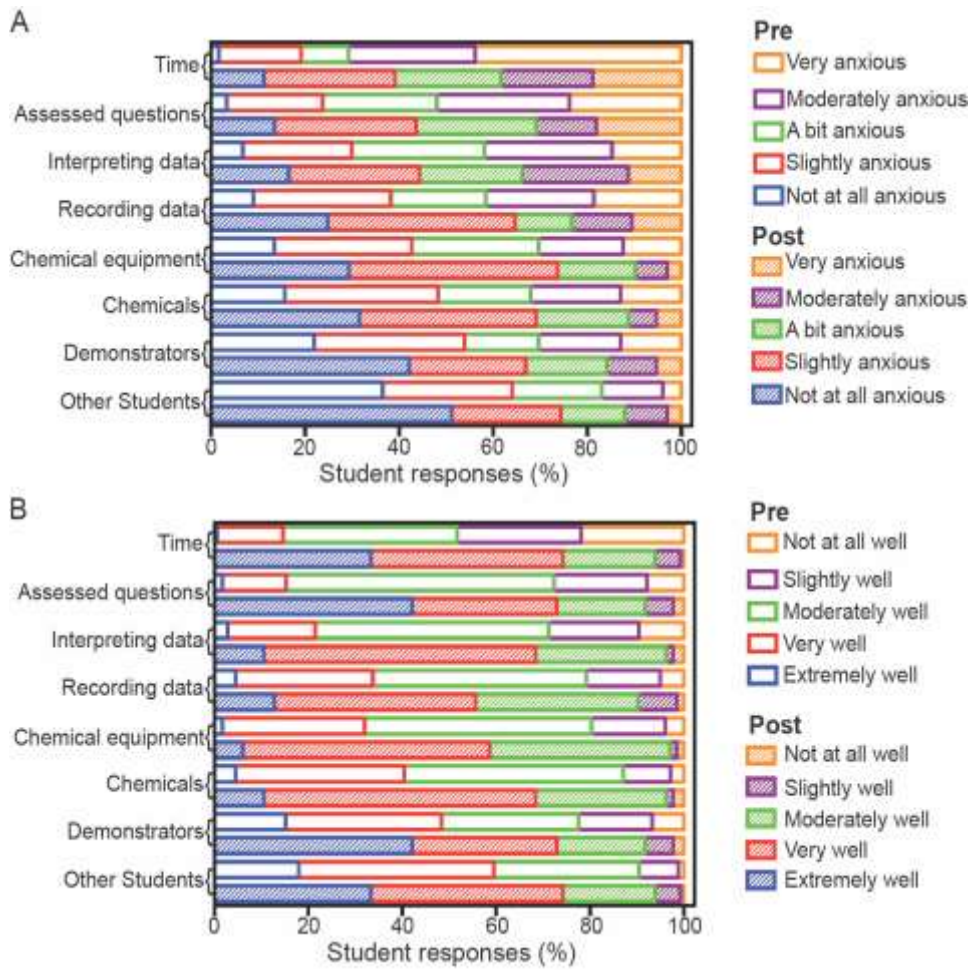

Figure 1. **Student responses to perceived levels of A) anxiety and B) self-efficacy towards different aspects of the laboratory at the beginning (pre) and end (post) of the semester. N=178 student responses pre and N=133 student responses post.**

The decrease in anxiety was also significant at the $p \leq 0.001$ level for each aspect except working with other students and interpreting data which were both significant at the $p \leq 0.05$ level. Z and p values (measures of effect size and significance) are available in Appendix C in the supplementary material.

3. What changes are seen between students' CLA and CLSE between the start of semester 1 and the start of semester 2?

We compared the data collected at the start of semester two with the data collected at the start of semester one. We expected to see that students who had already done a semester of study at a tertiary level had higher initial self-efficacy and lower anxiety than students

starting chemistry in first semester who had no prior university experience.

We observed that the only significant differences were that students at the start of semester two had higher self-efficacy about time management and lower anxiety about working with chemicals, recording data, and time-management. The changes are visually represented in figures 2A and 2B. More detailed statistical results can be found in Appendix D in the supplementary material. This supported the hypothesis that other mastery experiences and familiarity with the tertiary learning environment would improve students' CLSE and lower their CLA. However, without collecting further qualitative data it is not possible to draw any definite conclusions and this is certainly an area for further investigation.

4. What is the correlation between CLA and CLSE and how does this compare to the known correlation between CLA and general chemistry self-efficacy?

Spearman's rho correlation values as well as p values can be found in Appendix E of the supplementary material. The correlations between self-efficacy in one aspect of laboratory work and self-efficacy in another aspect of laboratory work were, on the most part, positive and significant. For example, students who were confident about their ability to work well with chemicals were also confident about their ability to record data, though, there was variation in the strength of these correlations.

Self-efficacy was significantly inversely correlated with anxiety for each of the same aspect of laboratory work. For example, students who were confident about their ability to work well with chemicals were also less anxious about working with chemicals. Generally, the strongest correlation was between self-efficacy and anxiety for a given aspect of laboratory work, e.g. self-efficacy about working with chemicals was more strongly correlated with anxiety about working with chemicals than anxiety about working with other students but there were exceptions (see Appendix E). The correlation between self-efficacy and anxiety for each aspect of laboratory work was significant at the $p \leq 0.001$ level in each set of results, except anxiety and self-efficacy about working with chemicals at the start of semester two which was only significant at the $p \leq 0.05$ level. If anxiety about working with chemicals was due to safety concerns it would logically follow that being able to work well with chemicals may give some reassurance. However, other aspects of laboratory work, such as recording data, may show a closer correlation as being able to record the data would entirely avoid the "threat" of not getting the data collected.

The results of this study also add to the growing number of studies that investigate the relationship between anxiety and self-efficacy in different fields. In a recent study involving the teaching and learning of mathematics the most important variable affecting mathematics anxiety was self-efficacy belief towards mathematics (Unlu, Ertekin, & Dilmac, 2017). In a broader context, the relationship of high self-efficacy and low anxiety is also reported for music teacher's computer usage (Kilic, 2015). This study shows that chemistry laboratory anxiety is not only correlated with chemistry self-efficacy in general as shown by Kurbanoglu and Akin (2010) but with chemistry laboratory self-efficacy specifically. One implication of this is that building self-efficacy about laboratory skills may be a more effective way to reduce anxiety than just building self-efficacy about chemistry skills in general.

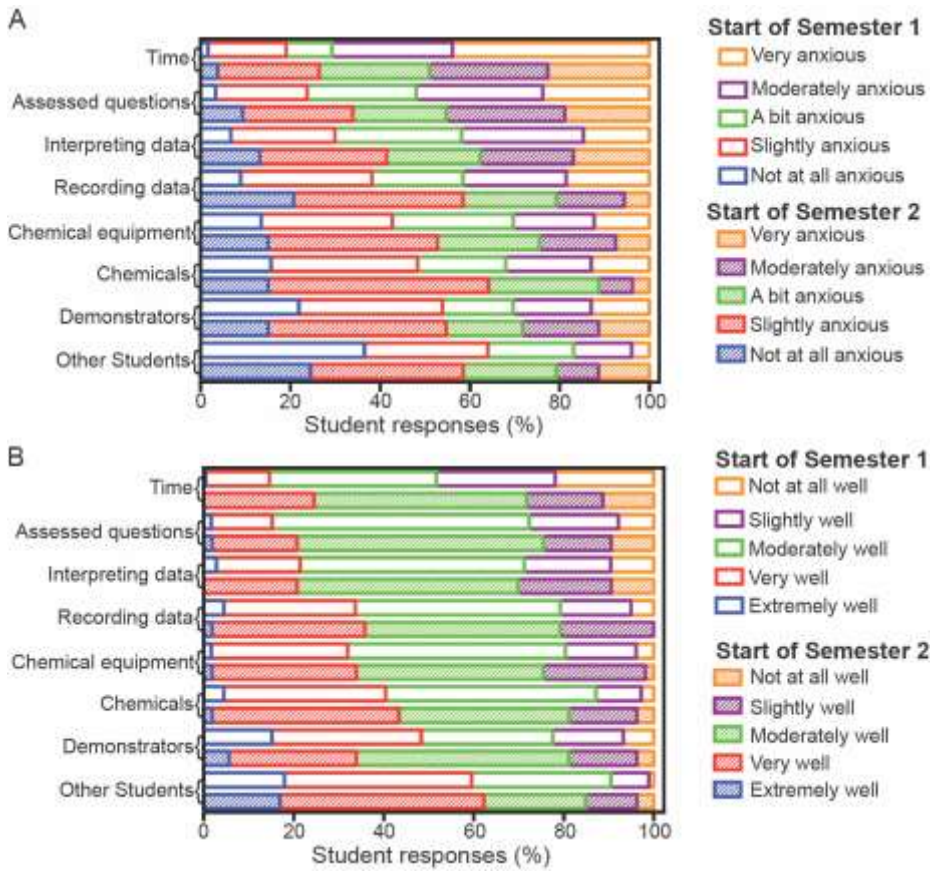

Figure 2. **A) Aspects of anxiety related to the chemistry laboratory at the start of semester 1 2017 (upper bar of pair) and the start of semester 2, 2017. B) Aspects of self-efficacy related to the chemistry laboratory at the start of semester 1 (upper bar of pair) and the start of semester 2, 2017. N=173 (Start of semester 1) N = 53 (Start of semester 2).**

5. Are the student characteristics of first language, prior and expected aversiveness, and desired and expected grade, correlated with CLA or CLSE?

English as a Second Language (ESL)

At the start of semester one, students who spoke English as a second language were significantly less anxious about working with chemicals ($Z = 3.517$, $p = < 0.001$), working with chemical equipment ($Z = 2.525$, $p = 0.012$), and answering assessed questions ($Z = 2.121$, $p = 0.034$) and significantly more self-efficacious about their ability to work well with chemical equipment ($Z = 2.584$, $p = 0.010$), complete the work in time ($Z = 2.312$, $p = 0.021$), ask for help from a demonstrator ($Z = 2.191$, $p = 0.28$) and answer assessed questions ($Z = 2.121$, $p = 0.034$) than native English speakers. Further research will be required to determine the reasons for this and whether international education systems play a role.

At the end of semester one, students who spoke English as a second language were significantly less anxious about working with chemicals ($Z = 2.629$, $p = 0.009$) and significantly less self-efficacious about their ability to work well with other students ($Z = 2.736$, $p = 0.006$), than native English speakers. This could either be due to a larger increase in self-efficacy and larger decrease in anxiety for native than non-native speakers or a smaller increase in self-efficacy and smaller decrease in anxiety for non-native speakers. More research should be done into ESL students' interactions with their peers and why they finish the semester significantly less confident about their ability to work well with other students.

At the start of semester two there were no significant differences between students who spoke English as a second language and students who were native speakers of English. This indicates that after a semester in an English-speaking university language is less of a perceived barrier to doing well.

Prior Experience

Students were asked to rate how aversive their most-recent prior experience of formal chemistry education had been and how aversive they expected the current unit to be. In every set of data there was a positive correlation between prior and expected aversiveness at the $p \leq 0.001$ level. This means that students who thought their prior experience was more aversive expected the current unit to be more aversive.

Expected aversiveness was the best predictor of high anxiety and low self-efficacy. At the start of semester one, when students prior experience would have been their exposure to chemistry at school, there was a correlation between low self-efficacy and high anxiety for each aspect of laboratory work at the $p \leq 0.001$ level. The only exceptions were anxiety about working with equipment and self-efficacy about working with other students (only significant at the $p \leq 0.05$ level). Anxiety about working with other students for which the correlation with expected aversiveness was not significant but for which the correlation with prior aversiveness was significant at the $p \leq 0.001$ level.

Clearly prior aversiveness is not the only predictor of expected aversiveness but given the strong correlation between the two it is likely that more aversive prior experiences negatively impact students' self-efficacy and increases their anxiety. The students taking this unit who reported higher levels of prior aversiveness may not necessarily be continuing on with a chemistry degree and as a result may see less relevance in the laboratories in the course. This could also impact student's perceptions of how relevant the laboratories are on their studies, which might be a factor effecting self-efficacy and anxiety. There are studies that link prior chemistry experiences to the perception of relevance for nursing students, where low achieving students find less relevance in their studies (Boddey & de Berg, 2015).

Grades

Expected aversiveness was also inversely correlated with expected grades. Students who rated their prior experience as more aversive expected lower grades. This may reflect prior experiences of getting poor grades which then set students up to expect lower grades in the tertiary environment as well. Students who expected lower grades at the start of semester one had significantly lower self-efficacy about each aspect of laboratory work except working with other students. They also had higher anxiety about recording data, completing the work in time, asking for help from a demonstrator, interpreting the data and answering assessed questions. Students who expected a higher grade generally also desired a higher grade than those who expected a lower grade.

Limitations of the Study and Future Directions

This study proposes the use of a newly developed questionnaire-survey, the CLASEQ, to assess the relationship between laboratory anxiety and self-efficacy. This questionnaire-survey was based on the validated factors previously determined to be important with regards to student anxiety in the laboratory by Bowen (1999). The CLASEQ also asks students about their anxiety regarding a number of aspects of laboratory work not considered by Bowen (1999), and about their chemistry laboratory self-efficacy. The CLASEQ herein was demonstrated in a first-year chemistry laboratory setting however, the instrument could be used in other undergraduate laboratories of the sciences and at different year levels due to the factors addressed likely to be the source of anxiety in other laboratory settings and year levels. Future work on the CLASEQ will aim to validate the newly added factors to those already validated by Bowen. To do this factor analysis across multiple institutions and multiple subjects is suggested as the most robust method.

Conclusion

This study reinforces the correlation between lower self-efficacy and higher anxiety. Therefore, educators at a tertiary level who want to reduce the anxiety felt by their students may do well to investigate strategies to improve self-efficacy as an intervention. The CLASEQ is expected to prove useful in such a situation as a tool for educators to use in order to evaluate the impact of any such interventions on both CLA and CLSE at once. In interventions targeting CLA or CLSE there should be a focus on the aspects which students have lowest self-efficacy about. In the tertiary chemistry laboratory these are likely to be aspects that directly impact students' grades (in our case time-management, answering assessed questions and interpreting data). These aspects are likely to be transferable to a greater number of different disciplines. Educators should also pay attention to the opportunity afforded by the first semester for students to acquire mastery experiences given the significant reduction in anxiety and increase in self-efficacy seen from the start to the end of the semester in this study. Further study needs to be done into the reasons behind why students at the start of their second semester reported significantly lower self-efficacy and higher anxiety about certain aspects of laboratory work.

The strong correlation between prior aversiveness and expected aversiveness for first-year university students shows the importance of high school experiences in shaping expectations about university. The correlation between prior aversiveness and higher CLA and lower CLSE show that negative experiences at a high school level have continuing effects in tertiary education, highlighting again the importance of experiences in the affective domain at a secondary level of education. Secondary educators who want to prepare their students well for tertiary experiences should therefore pay attention to improving the students' affective experiences of the subject.

It would be of interest to explore the reasons behind why students who speak English as a second language have significantly higher self-efficacy and lower anxiety about certain aspects and whether this relates to their secondary education experiences. It will also be of interest to further investigate the disappearance of these differences from the start to end of the semester and between the start of the first and second semesters. Given the significantly lower-self-efficacy about working with others reported by ESL students at the end of the semester educators should aim to promote positive interactions between students and especially the inclusion of non-native speakers of English.

Lastly, given that the students who desire higher grades are less anxious and more self-efficacious it should be clear that anxiety is not the primary motivator for students to achieve. Some arousal is necessary for alertness but given that the more motivated students are less anxious it's clear that reducing anxiety will not necessarily result in unmotivated students. Educators at both a tertiary and secondary level should aim to create experiences that contribute to positive affective experiences for students.

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