USING INTERACTIVE PRE-LABORATORY ACTIVITIES TO INCREASE FIRST-YEAR CHEMISTRY STUDENTS’ SELF-EFFICACY AND TO REDUCE THEIR ANXIETY

Cara Rummey (BSc)
School of Molecular Sciences, Chemistry Education
This thesis is presented for the degree of Master of Research to the University of Western Australia.
2019
Author’s Statement:

I, Cara Jacqueline Rummey, certify that:

This thesis has been substantially accomplished during enrolment in this degree.

Part of this work was submitted for the degree of honours in chemistry, however an application was made to upgrade this degree to a Master of Research. Otherwise, the work put forward in this thesis has not been submitted previously for a degree or diploma at the University of Western Australia or at any other university. In the future, no part of this thesis will be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of The University of Western Australia and where applicable, any partner institution responsible for the joint-award of this degree.

This thesis does not contain any material previously published or written by another person, except where due reference has been made in the text and, where relevant, in the Authorship Declaration that follows.

This thesis does not violate or infringe any copyright, trademark, patent, or other rights whatsoever of any person. The research involving human data reported in this thesis was assessed and approved by The University of Western Australia Human Research Ethics Committee. Approval #: RA/4/1/9011.

This thesis contains published work and/or work prepared for publication, some of which has been co-authored.

Signature: 

Date: 18/03/2019
Author Declaration for Co-Authored Publications

This thesis contains work that has been published.

Details of the work:

Location in thesis:
Chapter Three

Student contribution to work:
Research planning, data collection, data analysis and the majority of the writing up of the paper.

Co-author signatures and dates:

(Dr. Dino Spagnoli)
18/03/2019

Student signature:

Date: 18/03/2019

I, Dr Dino Spagnoli, certify that the student’s statements regarding their contribution to each of the works listed above are correct.

As all co-authors’ signatures could not be obtained, I hereby authorise inclusion of the co-authored work in the thesis.
Abstract:

Laboratory work is a significant component of most tertiary chemistry courses. However, they can also be a source of anxiety for students. The goals of the research project were; firstly, to learn more about level-one tertiary students’ chemistry laboratory anxiety (CLA) and the relationship of this anxiety to their chemistry laboratory self-efficacy (CLSE). Secondly, to apply what is learned about students’ CLA and CLSE in the development of pre-laboratory activities. Finally, to evaluate these pre-laboratory activities as an intervention to reduce CLA and increase CLSE. Through the development and use of a questionnaire, it was found that students are most anxious about having enough time to complete the laboratory tasks, answering assessed questions, and interpreting data. There was also a strong inverse correlation between CLA and CLSE. Additional factors contributing to students’ CLA were identified. These were: answering assessed questions, interpreting data, and asking for help from demonstrators. This improved understanding of students’ CLA and CLSE informed the design of interactive pre-laboratory activities. Feedback was collected from students in the lab, online and in interviews and was used to improve the second and third generations of the pre-laboratory activities. Students believed that the pre-laboratory activities were helpful and that the activities reduced their CLA and increase their CLSE. However, future studies will be necessary to quantify this effect.
Acknowledgments:
Firstly, I would like to acknowledge God, as without his grace this thesis would not have been written.

For their academic contributions, I would like to thank: Dr. Dino Spagnoli, Dr. Tristan Clemons, Professor Bob Bucat, Dr. Miriam Sullivan, Dr. Ann Grand, Miela Kolomaznik, the UWA Chemistry Education Research Group, the UWA Science Communication Research Group, and Dr. Lies Notebaert.

For their support, I would like to thank, George Stuart (Gramps), Dr. Jacqueline Rummey (Mum), Johanna Noppers and Hannah Hill.

In recognition of the importance of educators I would like to thank the following teachers of mine: Mrs Cheryl Jones (Year 3), for fostering her intrinsic curiosity, Mrs Paula McGibbon (Year 7), for challenging her to think critically, Mrs Catherine Williams (Years 8-9 and 12), for genuinely caring, Mrs Lesley Darlaston (Years 8-12), for her long-term support, Dr. Ala Altraide (Years 11 and 12), for his patience and tireless persistence, and Mrs Jenna Loney (Years 11 and 12), for encouraging me to be hopeful.

This research was supported by an Australian Government Research Training Program (RTP) Scholarship
3.5 Changes in Students’ Anxiety and Self-Efficacy from the Beginning to the End of a Semester ................................................................. 42
4.6 Correlation Between Students’ Anxiety and Self-Efficacy .......................... 43
3.7 Students’ Anxiety, Self-Efficacy, and Their Expectations about Grades and Aversiveness ......................................................... 44
3.8 Summary .................................................................................... 45
4.0 DEVELOPMENT OF AND FEEDBACK ON THE FIRST GENERATION OF PRE-LABORATORY ACTIVITIES ................................................................. 46
4.1 Introduction ................................................................................. 46
4.2 Development of the First Generation of Pre-Laboratory Activities ............. 46
4.3 Evaluation of the Second Generation of Pre-Laboratory Activities: Feedback Survey Results ................................................................. 50
   Evaluation of the First Generation of Pre-Laboratory Activities: Perceived Difficulty ................................................................. 53
   Evaluation of the First Generation of Pre-Laboratory Activities: Productive Worry .54
4.4 Evaluation of the First Generation of Pre-Laboratory Activities: Case Studies ...... 55
   Sophie – Interview One .................................................................. 56
   Rachel – Interview One ................................................................ 58
   Rachel – Interview Two ................................................................ 58
   Gilbert -Interview One .................................................................. 60
   Gilbert -Interview Two .................................................................. 61
4.5 Summary .................................................................................... 62
5.0 DEVELOPMENT OF AND FEEDBACK ON THE SECOND GENERATION OF PRE-LABORATORY ACTIVITIES ................................................................. 64
5.1 Introduction ................................................................................. 64
5.2 Development of the Second Generation of Pre-Laboratory Activities .......... 64
5.3 Evaluation of the Second Generation of Pre-Laboratory Activities: Feedback Survey Results ................................................................. 65
   Students’ Perceptions of the Importance of Aspects of Laboratory Work ........ 66
5.4 Evaluation of the Second Generation of Pre-Laboratory Activities: Case Studies... 71
   Faith ............................................................................................... 71
   Rhett ............................................................................................. 74
   Daisy ............................................................................................. 78
   Jake ............................................................................................... 79
   Kyle ............................................................................................... 80
   Maya ............................................................................................. 83
5.5 Summary .................................................................................... 86
6.0 DEVELOPMENT OF AND FEEDBACK ON THE THIRD GENERATION OF PRE-LABORATORY ACTIVITIES ................................................................. 88
6.1 Introduction ........................................................................................................ 88
6.2 Changes from the Second to the Third Generation of Pre-Laboratory Activities .... 88
6.3 Evaluation of the Second Generation of Pre-Laboratory Activities: Survey Results 91
   Students’ Perceptions of Their Mistakes, Anxiety and Confidence .................... 92
   Students’ Reasons for Completing the Pre-Laboratory Quizzes and Interactive Activities .............................................................. 93
   Students’ Perceptions of the Pre-Laboratory Activities: Perceived Difficulty .... 94
6.4 Evaluation of the Third Generation of Pre-Laboratory Activities: Case Studies .... 95
   Noah ...................................................................................................................... 96
   Vanessa .............................................................................................................. 99
   Samantha .......................................................................................................... 102
   William ............................................................................................................. 106
6.5 Summary .......................................................................................................... 110
7.0 STUDENTS’ CLA AND CLSE DURING AN INTERVENTION ......................... 111
7.1 Introduction ....................................................................................................... 111
7.2 Results from Semester Two 2017 ................................................................. 111
   Comparison with Semester One 2017: Aspects of Chemistry Laboratory Work & Anxiety ........................................................................ 111
   Comparison with Semester One 2017: Aspects of Chemistry Laboratory Work & Self-Efficacy ............................................................... 112
   Demographic Changes Throughout 2017 ......................................................... 113
   Changes in Anxiety and Self-Efficacy from the Start to the End of Semester Two 2017 .......................................................... 114
7.3 Results from Semester One 2018 .................................................................... 116
   Comparison with 2017: Anxiety and Self-Efficacy About Aspects of Laboratory Work ................................................................. 116
   Correlations Between Anxiety and Self-Efficacy at the Beginning of Semester One 2018 ................................................................. 117
   Changes in Anxiety and Self-Efficacy During Semester One 2018 ................. 118
7.4 Results from Semester Two 2018 ...................................................................... 120
   Anxiety and Self-Efficacy Pre and Post Pre-Laboratory Activity Completion ... 120
   Anxiety and Self-Efficacy about Two New Aspects of Laboratory Work ......... 121
7.5 Summary .......................................................................................................... 123
8.0 LIMITATIONS AND FUTURE RESEARCH .................................................... 124
   Limitations ........................................................................................................ 124
   Recommendations for Future Research .......................................................... 125
9.0 CONCLUSIONS AND RECOMMENDATIONS ........................................126
Conclusions: Summary .............................................................................126
Conclusions: Answers to Research Questions ...........................................127
Recommendations for Pre-Laboratory Activity Development: ..................130
Recommendations for Pre-Laboratory Activity Evaluation: .......................130
10.0 REFERENCES ......................................................................................132
11.0 APPENDICES ....................................................................................139
Appendix A: Participant Information Form ................................................139
Appendix B: Participant Consent Form .......................................................140
Appendix C: The CLASEQ .......................................................................141
Appendix D: Means and Standard Deviations of CLASEQ Results at the start of Semester One 2017 for three Level One Chemistry Units ..........................145
Appendix E: Mann-Whitney U Test CLASEQ Results at the Start and End of Semester One, 2017 .................................................................145
Appendix F: Spearman Rho Correlations Between Aspects of CLA and Aspects of CLSE ............................................................................146
Appendix G: Feedback Survey Distributed After the First Pre-Laboratory Activity in Semester Two 2017 ..............................................................147
Appendix H: Feedback Survey Distributed After the Final Pre-Laboratory Activity in Semester Two 2017 ..............................................................148
Appendix I: Interview Two Prompts Semester Two 2017 ............................155
Appendix J: Feedback Survey Semester One 2018 .....................................156
Appendix K: Interview Prompts from Semester One 2018 ............................160
Appendix L: Feedback Survey Semester Two 2018 .....................................161
Appendix M: Interview Prompts Semester Two 2018 ....................................167
Appendix N: Hypothesised Model for the Interaction of Students’ CLA, CLSE, Prior Experience, Valuing of Laboratory Work and Pre-Laboratory Completion ....168
1.0 INTRODUCTION AND LITERATURE REVIEW

1.1 Origins of the Thesis

In 2017, the chemistry education research group at the University of Western Australia (UWA) published a paper investigating the effects of a “prepare, do, review” (PDR) model for laboratory teaching on students’ feelings about the laboratory (Spagnoli, Wong, Maisey, & Clemons, 2017). The authors observed that students had more negative feelings about the laboratory sessions than was desired. While the implementation of the PDR model resulted in improvements to students’ feelings about the laboratory, the authors called for further investigation into the origin and nature of these negative feelings.

The study on the PDR model showed that, prior to the intervention, students’ anxiety increased during the semester and their confidence decreased (Spagnoli, Wong, Maisey, & Clemons, 2017). This was concerning as it would be hoped that students were gaining not only laboratory skills, but also confidence in their skills, during the semester. Another reason for concern is that high levels of anxiety have been found to negatively impact academic success, (Abendroth & Friedman, 1983; Westerback & Primavera, 1992). However, it is not surprising that an increase in anxiety coincided with a decrease in confidence, given the known inverse correlation between anxiety and self-efficacy found by Kurbanoglu and Akin (2010). Kurbanoglu and Akin (2010) define self-efficacy as “a person’s beliefs concerning his or her ability to perform successfully on a given task,” (p.50). This could be rephrased as confidence in one’s ability to do a task well.

This master’s project aims to continue this investigation into students’ negative feelings towards the laboratory, focussing on anxiety and self-efficacy. It also aims to apply these findings to develop a series of pre-laboratory activities for use and evaluation as an intervention to reduce chemistry laboratory anxiety (CLA) and build chemistry laboratory self-efficacy (CLSE).
1.2 Structure of the Thesis

This thesis will begin by discussing the background literature, followed by the context of the study and the methods used. Chapter three, will discuss the data regarding level-one students’ CLA and CLSE collected prior to the introduction of interactive pre-laboratory activities. Chapters four, five and six will discuss the development of the first, second and third generations of the pre-laboratory activities respectively, and student feedback collected via surveys and interviews. Chapter seven will discuss the data regarding students CLA and CSLE collected during the intervention. Following which are the limitations and recommendations for future research. Lastly, there is a summary of the findings with recommendations for educators who may want to implement either a similar intervention or evaluation.

1.3 Review of the Literature

Laboratory sessions are an integral part of any undergraduate tertiary science course. They are used to teach students important practical skills and are an opportunity for students to apply the theory of the course in a practical context. A landmark review of the role of tertiary chemistry laboratories defines the main teaching outcomes as, “skills relating to learning chemistry, practical skills, scientific skills, and general skills.” (Reid & Shah, 2007). Due to the necessity of the skills learned in undergraduate laboratories, it is important that educators help students to make the most of this learning opportunity.

Furthermore, the extent to which a student interacts and learns in an undergraduate chemistry laboratory depends on how they think and feel towards the laboratory (Galloway & Bretz, 2015). Therefore, understanding the affective domain of students’ experiences is an important step in any strategy to assist students to succeed in making the most of their undergraduate chemistry laboratory classes (DeKorver & Towns, 2016; Galloway & Bretz, 2015; Galloway, Malakpa, & Bretz, 2016).
1.4 Anxiety, Self-Efficacy and Learning

The Affective Domain and Students’ Learning

There is an established link between self-efficacy and achieving good grades (Britner, 2008; Multon, Brown, & Lent, 1991), though the strength of this correlation is debated (Bartimote-Aufflick, Bridgeman, Walker, Sharma, & Smith, 2016; Honicke & Broadbent, 2016). Self-efficacy is also correlated with students’ intrinsic motivation to learn which is a known predictor of academic success (Ross, Perkins, & Bodey, 2016). Given the importance of self-efficacy, it is worth considering its sources. These include: mastery experiences, vicarious experiences, social persuasions, and psychological states (Bandura, 1977; Britner, 2008). Of these, mastery experiences are the strongest predictor of high self-efficacy (Britner, 2008; J. A. Chen & Usher, 2013). However, drawing from multiple sources has a positive synergic effect on self-efficacy (Chen and Usher, 2013). As students’ abilities to plan and perform laboratory experiments improve with experience, so does their self-efficacy (Winkelmann et al. 2014).

In contrast, anxiety is inversely correlated with students’ grades according to previous researchers’ results (Abendroth and Friedman, 1983; Westerback and Primavera, 1992) and chemistry laboratory work can be a source of anxiety for students (Eddy, 2000). There has been debate about whether some anxiety can be helpful (Nesse, 1994). Pekrun (2006) classifies anxiety as an activating emotion but notes that while anxiety may provide an extrinsic motivation, it is complex as it also reduces interest and intrinsic motivation. This is important because research shows that students who have a strong intrinsic motivation to learn are much more likely to have high self-efficacy (Ross et al., 2016). It has also been suggested that it is not whether people feel anxiety, but how they react to that anxiety that determines whether it is adaptive or maladaptive (Conway, Wood, Dugas, & Pushkar, 2003).
In this discussion it is important to distinguish between the cognitive aspect of anxiety (worry), and the somatic aspect of anxiety (arousal) (Conway et al., 2003; Morris, Davis, & Hutchings, 1981; Zeidner, 1998). The amount of arousal that is adaptive, leading to alertness, and the amount which is maladaptive, depends on the situation. Furthermore, there is a type of worrying that may be productive (Leahy, 2002). For example, asking oneself before the laboratory what can be done to prepare and ensure that the laboratory goes well may prove productive. There is also a type of worrying that is unhelpful. For example, spending the time before the laboratory worrying about the consequences if it does not go well, which achieves nothing. The goal of anxiety reduction is not that students are unconcerned and apathetic, but that they are not distracted by either somatic symptoms of anxiety, or by worrying about failure and the potential consequences.

Although there is research on anxiety, self-efficacy and academic achievement, there is little research on anxiety, self-efficacy and achievement of the actual learning outcomes. Nevertheless, pedagogies that aim to help students achieve the learning outcomes have been shown to have a positive impact on anxiety and self-efficacy (Ural, 2016; Winkelmann et al., 2014). This is suggestive that there may indeed be a connection between CLA, CLSE and achievement of learning outcomes. Therefore, it is important to consider how CLA might be reduced and how CLSE might be improved.

**Measuring Chemistry Laboratory Anxiety (CLA)**

The Chemistry Laboratory Anxiety Index (CLAI) is used to measure the contribution of five factors to CLA (Bowen, 1999). The five factors considered by the CLAI are: working with chemicals, using equipment, collecting data, working with other students, and having adequate time. This index measures specific sources of anxiety in chemistry laboratories rather than overall anxiety.
The ability to measure specific factors contributing to CLA is of high importance, as within the demographic of students in Australian universities, generalized anxiety disorder has a prevalence of approximately 17.5% (Farrer, Gulliver, Bennett, Fassnacht, & Griffiths, 2016). The CLAI has been used multiple times in the literature as a tool to measure students’ chemistry laboratory anxiety (Kurbanoglu & Akim, 2010; Spagnoli, Wong, Maisey, & Clemons, 2017; Ural, 2016).

However, there is a lack of work testing whether the aspects of chemistry laboratory work identified as factors in the CLAI are exhaustive or not. An example of a potential aspect of laboratory work that may cause students anxiety not considered by the CLAI is test-anxiety. Students are often assessed in the laboratory and assessment has been shown to produce a distinct type of anxiety in some students (Zeidner, 1998). Looking for additional aspects of chemistry laboratory work that contribute to CLA is one of the aims of this thesis.

**Correlation Between CLA and Chemistry Self-Efficacy**

One study of the CLAI found a correlation between high chemistry laboratory anxiety and low general chemistry self-efficacy (Kurbanoglu and Akim, 2010). The literature has called for further investigations into this relationship between anxiety and self-efficacy in the chemistry laboratory context (Honicke & Broadbent, 2016; Multon et al., 1991; Pajares, 1996).

Boddey (2012), showed an inverse correlation specifically between laboratory anxiety and laboratory self-efficacy, but only measured laboratory self-efficacy about working safely with chemicals, interpreting graphs and doing the procedures. Such work, while a good start, is limited and a better understanding of CLSE about specific aspects of laboratory work is one of the aims of this thesis.
1.5 Pre-Laboratory Activities and Students’ Feelings Towards the Laboratory

A couple of studies have noted that after doing pre-laboratory activities students were better prepared for the laboratory (Chaytor, Al Mughalaq, & Butler, 2017) or more autonomous (Limniou, Papadopoulos, Giannakoudakis, Roberts, & Otto, 2007) and equated these observations with self-efficacy. Another study showed that pre-laboratory activities reduced test-anxiety (Chu, 2017). However, few studies actually investigate the impact of pre-laboratory activities in the affective domain in much depth.

An exception to this is a paper on the use of the “prepare, do, review” model for reducing students’ negative feelings towards the chemistry laboratory (Spagnoli, Wong, Maisey, & Clemons, 2017). This study called for further investigation into which aspects of chemistry laboratory work contribute to students’ negative feelings towards chemistry laboratories. Specific attention was drawn to the need to better understand chemistry laboratory anxiety (CLA), which encompasses more than just chemophobia (a fear of chemicals).

Agustian and Seery’s (2017) review of the literature on the use and development of pre-laboratory activities categorised pre-laboratory activities into three types: those that introduced chemical concepts, those that introduced laboratory techniques and those that addressed the affective dimensions (Agustian and Seery, 2017). For introducing chemical concepts, they discussed the use of pre-laboratory lectures, quizzes or discussions. For introducing laboratory techniques, they discussed technique videos, interactive simulations, mental preparation and safety information. Finally, for addressing the affective dimensions they discussed the potential for pre-laboratory activities to improve students’ self-efficacy and motivation but admitted that very little research had been done and that more was needed.
Another study worth considering in more detail is the work of Dalgarno, Bishop, Adlong and Bedgood (2009), who looked at the viability of a virtual laboratory to familiarise students with the laboratory and thus increase their self-efficacy and reduce their anxiety. However, the study concluded that, although the virtual laboratory was successful in familiarising students with the laboratory, a lack of familiarity was not one of the main factors that contributed to students’ anxiety. Instead they concluded that future research ought to instead focus on preparing students to apply mathematical techniques and chemistry concepts within the practical sessions, as this was a greater source of anxiety. It is unclear how this was determined to be a greater source of anxiety, but it is possible that it was the result of the interviews that were conducted. Either way, this recommendation has not been explored, nor have the impacts of remote laboratory sessions on students CLA been investigated.

1.6 Literature Relating to the Development of Pre-Laboratory Activities

According to Novak’s theory of meaningful learning, there are three domains of learning: cognitive, psychomotor and affective (Galloway & Bretz, 2015; Novak, 1998). These correspond to the thinking, doing and feeling aspects of learning respectively. Although self-efficacy and anxiety belong in the affective domain, they can be interconnected with aspects in the cognitive and psychomotor domains. For example, a student can have high or low self-efficacy about their ability to do a vacuum filtration, a psychomotor skill. Additionally, since mastery experiences, such as successfully doing a vacuum filtration are the greatest predictors of self-efficacy, it is important to consider how pre-laboratories might provide, or lead to mastery experiences. For example, they may improve students’ cognitive and psychomotor skills, thus leading to an indirect increase of self-efficacy via mastery experiences. Alternatively, students may gain direct mastery experiences in answering questions like those that are asked in the laboratory.
Cognitive Domain: Cognitive Load, Bloom’s Taxonomy and Schema Development

One of the most common constructs for understanding the limitations of learners in the cognitive domain is the concept of cognitive load. Working memory limits how much information can be processed at a time (Winberg & Berg, 2007). The cognitive load is the amount of work the brain is asked to do in processing this information (Sweller, 1988). Cognitive load theory attempts to use this knowledge to inform teaching practices (Kalyuga, 2007; Paas, Van Gog, & Sweller, 2010).

The chemistry laboratory is an environment in which students are likely to experience a very high cognitive load (Hubacz Jr, 2004; Johnstone & Wham, 1982). Figure 1.1 shows some aspects of laboratory work that contribute to students’ cognitive load:

Figure 1.1: Some aspects of laboratory work that contribute to cognitive load. From Johnstone and Wham (1982)

A review of the existing literature on how cognitive load theory should inform pre-laboratory design (Winberg and Berg, 2007), found that providing students with theory before the laboratory freed up cognitive space during the laboratory for engagement with the content. Other research has suggested that worked examples could also reduce cognitive load (Crippen & Earl, 2007; Sweller, 1988, 1994). Additionally, the implementation of an interactive, pre-laboratory simulation, developed using cognitive-load theory, was found to increase students’ autonomy and perceived preparedness (Limniou et al. 2007). This was interpreted as an increase in students’ self-efficacy.
Bloom’s Taxonomy

The ways in which learners may engage in the cognitive domain are ranked in Bloom’s taxonomy. This is a hierarchy of cognitive skills, in which those skills at the bottom of the hierarchy are foundational to those that are built on them. The basic skill is knowledge, which is examinable by asking for a regurgitation of facts. The next is comprehension, where the learner can put concepts into their own words. Application involves using the knowledge that has been comprehended. Analysis is “where the skills that we commonly think of as critical thinking enter,” (Adams, 2015, pp. 152). Synthesis, as in the laboratory, is using what exists to create something new. In the case of Bloom’s taxonomy (Figure 1.2), this is generally the use and combination of existing ideas to generate novel ones. Lastly evaluation reflects the ability of the learner to critically compare ideas, identifying strengths and weaknesses, and make recommendations.

![Bloom's Taxonomy Diagram](image)

*Figure 1.2: Bloom’s Taxonomy, adapted from Alford, Herbert, and Frangenheim (2006)*

Bloom’s taxonomy describes the varying degrees to which knowledge is stored and applied and cognitive load theory includes a description of how information is processed.
However, neither discusses the way that ideas are stored and connected in the mind: this is the concept of schemas. A schema is a cognitive framework that enables an individual to make meaningful connections between learned pieces of information, and to apply this information in a range of different settings (Novak, 1998; G. Walker, 2013).

David Anusubel recognised this in his assimilation theory and proposed “reasoning capacity is primarily a function of the adequacy of the relevant conceptual framework a person has in a specific domain of knowledge” (Bretz et al. 2013, pp. 281). That is: schemas are necessary for learning. For Anusubel, connecting new information into an existing framework is necessary for meaningful learning (Ebenezer, 1992). Schema formation is necessary for the transfer of information from experience to long-term memory, which occurs via working memory (Kirschner, Kester, & Corbalan, 2010).

Cognitive overload hinders this process, and so it is recommended that educators aim to reduce cognitive load (Hubacz Jr, 2004; Kirschner et al., 2010). Although educators may see it as desirable for students to concurrently do the laboratory activities, and process the theory behind them, research shows that this is beyond the ability of most students (Hubacz, 2004). One solution is to shift some of the cognitive load to a pre-laboratory activity, so that students are able to operate at higher levels of cognition during the laboratory (Richards-Babb, Curtis, Smith, & Xu, 2014).

Also considered were Mayer’s principles for e-learning which include coherence, signalling, redundancy, contiguity, segmenting, pre-training, modality, personalisation, voice and embodiment (Mayer, 2017). These are explained well in an infographic designed by Michael Seery in 2017 (Figure 1.5). The three categories of reducing extraneous processing, managing essential processing, and fostering generative processing, relate to ways in which cognitive load can be reduced (Moreno & Mayer, 2010).
<table>
<thead>
<tr>
<th>Reducing extraneous processing</th>
<th>Managing essential processing</th>
<th>Fostering generative processing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coherence Principle</strong></td>
<td><strong>Segmenting Principle</strong></td>
<td><strong>Personalization Principle</strong></td>
</tr>
<tr>
<td>Exclude interesting but irrelevant material as this material reduces cognitive capacity to process essential material in a lesson.</td>
<td>Add self-pacing options to enable learners to process information before continuing.</td>
<td>Present words in conversational style rather than formal style, including the use of personal pronouns (I and you) in script, especially in early stages.</td>
</tr>
<tr>
<td><strong>Signalling Principle</strong></td>
<td><strong>Pre-training Principle</strong></td>
<td><strong>Voice Principle</strong></td>
</tr>
<tr>
<td>Include vocal cues and/or visual highlights to aid the selection and organisation of important information, especially for learners with low prior knowledge.</td>
<td>Provide option to view information on key terms to allow learners to familiarise before having to work with them.</td>
<td>Narration should use a human voice rather than a computer voice, and this should match any on-screen character.</td>
</tr>
<tr>
<td><strong>Redundancy Principle</strong></td>
<td><strong>Modality Principle</strong></td>
<td><strong>Embodiment Principle</strong></td>
</tr>
<tr>
<td>Graphics with narration alone is more effective than also including on-screen text. Adding one or two keywords as on-screen text has benefit.</td>
<td>Present information about a graphic verbally rather than as text so that learners can listen and refer to graphic, especially for system-paced dynamic graphics (e.g., videos).</td>
<td>Drawing graphics as you explain is more beneficial than explaining a presented drawing as it reflects a real-life social interaction.</td>
</tr>
<tr>
<td><strong>Contiguity Principles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Place printed words near any corresponding graphics, and coincide narration with related display.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Another way to prepare students to perform well at higher levels of Bloom’s taxonomy is to use a guided inquiry approach (Domin, 1999a, 1999b). In contrast to the common “cookbook” style, in which students reach a predetermined conclusion, guided-inquiry laboratories help students develop research skills (J. B. Allen, 1986). Figure 1.3 shows how structured guided-inquiry laboratories are compared to other types of laboratories:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Confirmation</th>
<th>Structured Inquiry</th>
<th>Guided Inquiry</th>
<th>Open Inquiry</th>
<th>Authentic Inquiry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem/Question</td>
<td>Provided</td>
<td>Provided</td>
<td>Provided</td>
<td>Provided</td>
<td>Not Provided</td>
</tr>
<tr>
<td>Theory/Background</td>
<td>Provided</td>
<td>Provided</td>
<td>Provided</td>
<td>Provided</td>
<td>Not Provided</td>
</tr>
<tr>
<td>Procedures/Design</td>
<td>Provided</td>
<td>Provided</td>
<td>Provided</td>
<td>Not Provided</td>
<td>Not Provided</td>
</tr>
<tr>
<td>Results Analysis</td>
<td>Provided</td>
<td>Not Provided</td>
<td>Not Provided</td>
<td>Not Provided</td>
<td>Not Provided</td>
</tr>
<tr>
<td>Results Communication</td>
<td>Provided</td>
<td>Not Provided</td>
<td>Not Provided</td>
<td>Not Provided</td>
<td>Not Provided</td>
</tr>
<tr>
<td>Conclusion</td>
<td>Provided</td>
<td>Not Provided</td>
<td>Not Provided</td>
<td>Not Provided</td>
<td>Not Provided</td>
</tr>
</tbody>
</table>

Figure 1.3: Classification of inquiry in teaching laboratories. adapted from Buck, Bretz, and Towns (2008)

Unfortunately, there is no concrete definition of a guided-inquiry laboratory. This does not render the concept entirely unhelpful however, as the core principles of genuine investigation are generally the same. Furthermore, despite the variance in styles, a general guided-inquiry approach can be used effectively to achieve the teaching goals in undergraduate chemical laboratories (Schoffstall & Gaddis, 2007). Guided-inquiry style laboratories have been connected to increased student motivation (Madhuri, Kantamreddi, & Prakash Goteti, 2012).

Guided-inquiry laboratories are also of interest because they have been successfully used to reduce chemistry laboratory anxiety (Ural, 2016). However, it has been suggested that the cognitive load imposed on student’s during the laboratory by an inquiry-based laboratory session leads to frustration (Hubacz, 2004).
It is expected that engaging students in guided-inquiry style pre-laboratory activities will motivate them and prepare them to do better when required to operate at higher levels of thinking in the laboratory. By asking questions students are prompted to make their own hypothetical choices and draw their own conclusions before providing feedback. This is a step towards inquiry and away from a follow-the-recipe approach.

**The Psychomotor Domain: Modelling Practical Skills and the Psychomotor Response Taxonomy**

A Bloom’s taxonomy-like system for classifying psychomotor responses was developed by E. J. Simpson (1966). In this taxonomy development of psychomotor skills begins before any actual action is performed as can be seen in Figure 1.4.

![Psychomotor response taxonomy](image)

**Figure 1.4: Psychomotor response taxonomy.**

Modelling skills gives learners important information about how to successfully perform tasks, which can help in the development of motor skills (McCullagh, Weiss, & Ross, 1989). In addition, modelling has been shown to increase learners’ self-efficacy relating to their motor skills, and reduce their anxiety (McCullagh, Weiss and Ross, 1989). This may be in part because modelling provides vicarious mastery experiences, which have been shown to increase self-efficacy (Britner, 2008).
Also, it has been found that video demonstrations and live demonstrations positively impact motor-skill self-efficacy, even for tasks participants would rather avoid (Feltz, Landers, & Raeder, 1979) with no significant difference between live and video modelling. Video modelling has been made increasingly possible in recent years due to increases and advancement in technology, and, as technology has been integrated into educational settings researchers have speculated over its limitations.

Attempts to virtually replicate the laboratory experience have thus far led to the conclusion that digital representations of the laboratory ought to be used alongside rather than in place of physical laboratory sessions (Potkonjak et al., 2016; Ramos, Pimentel, Maria das Graças, & Botelho, 2016). This is because students need opportunities to physically practice the motor skills necessary for future employment (Ramos et al. 2016; Potkonjak et al. 2016), and is consistent with Feltz, Landers and Raedar’s (1979) findings that after seeing a skill modelled, learners must then apply what they have learned. Their research also shows participant modelling, that is: modelling followed by guided participation and mastery experiences, was a stronger predictor of self-efficacy than modelling alone (Feltz, Landers and Raeder, 1979).

Affective Domain: Control-Value Theory, Students’ Values, Online Resource Quality, Gamification and Motivation

Control Value Theory

According to control-value theory, anxiety arises when a person anticipates potential failure, values success, and does not have enough control to be certain they can avoid failing (Pekrun, 2006). For example, a student who values obtaining a high yield, but lacks self-efficacy, will become anxious. Whereas, a student who does not care about getting a high yield will not be anxious, even if they lack self-efficacy. Additionally, a student who cares and has high self-efficacy, will be less anxious than a student who has less self-efficacy.
This is consistent with the inverse correlation seen between anxiety and self-efficacy. Based on the framework of control-value theory, it is expected that pre-laboratory activities will be more effective at reducing anxiety if they consider the aspects of laboratory work valued by students, rather than just the aspects valued by educators.

**Online Resource Quality**

As online technology is increasingly being used in tertiary education, both for teaching and assessment (Jolley, Wilson, Kelso, O’Brien, & Mason, 2016; O’Callaghan, Neumann, Jones, & Creed, 2017). It is therefore not surprising then, that research has been conducted to probe how students feel about this kind of technology, and how it can impact their learning. Factors that have been found to contribute to the effectiveness of online teaching resources include: students’ training in technology use (Fish & Wickersham, 2009), user-friendliness (Almala, 2007), digital-resource quality (WinklerPrins, Weisenborn, Groop, & Arbogast, 2007) and interactivity (Gaber, Naseef, & Abdelbaki, 2013).

**Gamification**

Research has also been conducted into the effect of gamification on learning. Distinct from educational gaming, gamification refers to the introduction of gaming elements into a non-gaming context (Schaffhauser, 2017) although both have been shown to have educational benefits (Maul, 2016). For example, the introduction of digital badging to evaluate students’ laboratory performance improved both students’ skills and self-efficacy (Hensiek et al., 2016). The use of multimedia elements (text, animation, sound, video, and graphics) is an effective way to increase the interactivity of online laboratories (Gaber et al., 2013). Also, implementing gamification in a pre-laboratory activity is promising for improving the attitudes of students towards learning chemistry (Burkey, Anastasio, & Suresh, 2013). Multimedia elements and interactions were introduced into the first generation of pre-laboratory activities for this reason.
Motivation

Also, important when considering the affective domain is motivation. A student is said to have intrinsic motivation when the enjoyment of the task is motivating in itself (Deci, 1971). This contrasts with extrinsic motivation, where some external reward motivates behaviour, and amotivation, where there is no motivation. In a working environment, increasing preparedness increases intrinsic motivation (Salmela-Aro, Mutanen, & Vuori, 2012). Therefore, pre-laboratory activities are also expected to increase intrinsic motivation. Intrinsic motivation is correlated with greater persistence in academic tasks (Vallerand & Bissonnette, 1992), higher self-efficacy, lower anxiety, and academic success (Bates, 2007; Goldberg & Cornell, 1998). Additionally, students who are intrinsically motivated are more likely to engage at higher cognitive levels (C. O. Walker, Greene, & Mansell, 2006). This supports the idea that designing pre-laboratory activities that prepare students for the laboratory may increase their CLSE and reduce their CLA.

1.7 Summary

Experiences in the affective domain are a necessary part of meaningful learning. Two constructs in this domain are anxiety and self-efficacy. These have been shown to be inversely correlated. Pre-laboratory activities are a potential intervention to reduce students’ CLA and increase their CLSE. This may occur directly through as a result of seeing skills modelled or virtual mastery experiences afforded by practice questions. It may also occur indirectly as students build schemas that reduce the cognitive load experienced during the laboratory, resulting in more mastery experiences in the laboratory as they are better able to engage at higher levels of Bloom’s taxonomy and meet the laboratory requirements. There is also anecdotal data in the literature to support the hypothesis that pre-laboratory activities may reduce anxiety and increase self-efficacy. However, there is an absence of in-depth research on this subject.
1.8 Significance of the Thesis

In order to improve students’ meaningful learning in the laboratory it is important to
develop a better understanding of the affective dimension of their experiences (DeKorver &
Towns, 2015; Galloway & Bretz, 2015; Galloway, Malakpa, & Bretz, 2015). Therefore,
it is important to investigate which aspects of laboratory work they are anxious about or
lack self-efficacy about. Additionally, a review paper published midway through this
masters’ project affirmed our findings that little had been done to investigate the effect of
pre-laboratory activities in the affective domain (Agustian & Seery, 2017). They noted
that several papers observe increases in self-efficacy or decreases in anxiety as a result of
introducing pre-laboratory activities. However, this was generally done without
quantification or much further investigation.

The significance of this project can be summarised as follows: the affective domain
impacts students’ learning but there has been insufficient research into students’ CLA and
CLSE. Furthermore, there has been insufficient research into the use of pre-laboratory
activities to address this, despite observations suggesting they may be effective.

Knowing what students are anxious about is an integral first step in developing
interventions to further reduce negative feelings about the chemistry laboratory. As
Dalgarno, Bishop, Adlong, and Bedgood Jr (2009) emphasised in their recommendations
for future work, interventions to improve self-efficacy ought to first investigate which
aspects of laboratory work regarding which students lack self-efficacy, and then develop
an intervention, rather than developing the intervention first. Identifying the aspects of
laboratory work about which students have high CLA and low CLSE and addressing these
specifically is central to this study. Once developed the pre-laboratory activities were
evaluated as an intervention via a mixed methods approach.
1.9 Research Questions of the Thesis

There were three main research questions that guided this study. Each of these questions was supported by several sub questions, listed below the main questions.

1. What is the nature of students’ chemistry laboratory anxiety and self-efficacy in the context in which this study was conducted?

2. How can interactive pre-laboratory activities be developed and improved as an intervention to reduce students’ CLA and to improve their CLSE?

3. How can interactive pre-laboratory activities be evaluated as an intervention to reduce students’ CLA and to improve their CLSE?

The expected outcomes of this study were to:

1. Expand the current understanding of the aspects of chemistry laboratory work that contribute to students’ CLA and how this is correlates with the aspects of laboratory work they lack self-efficacy in.

2. Develop pre-laboratory activities that model cognitive and practical laboratory skills resulting in increased CLSE for students and a subsequent reduction in CLA.

3. Evaluate the ability of the pre-laboratory activities to increase students’ CLSE and reduce their CLA about various aspects of laboratory work.
2.0 CONTEXT AND METHODOLOGY

2.1 Context

This study was conducted at the University of Western Australia in Perth. It was conducted across the academic years 2017 and 2018 (which begins at the end of February and finishes mid-November).

The students who participated in this study were enrolled in at least one first-year chemistry unit at the University of Western Australia. In semester one data were collected from students enrolled in three different level-one units (Table 2.1).

*Table 2.1:* The three level-one chemistry units

<table>
<thead>
<tr>
<th>Unit</th>
<th>Number of Students Enrolled During Semester One 2017</th>
<th>Purpose</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHEM1001</td>
<td>214</td>
<td>Foundational Unit</td>
<td>Introduction to Physical Chemistry. Topics include thermodynamics, kinetics, equilibria and electrochemistry.</td>
</tr>
<tr>
<td>CHEM1002</td>
<td>255</td>
<td>Foundational and Service Unit</td>
<td>Introduction to Organic Chemistry. Topics include the properties and basic reactions of simple organic compounds.</td>
</tr>
<tr>
<td>CHEM1003</td>
<td>288</td>
<td>Bridging and Service Unit</td>
<td>Upper-Secondary School Chemistry. Topics include atomic structure, chemical bonding, reactions, redox reactions and energy changes in reactions.</td>
</tr>
</tbody>
</table>
Pre-laboratory activities were then developed for students enrolled in CHEM1002 only. The rest of the research was conducted with the participation of students from CHEM1002 (Table 2.2). This unit was chosen as there was a pre-existing YouTube video, which had some interactivity in the form of three questions built into the online video. Students could click the answer and the video would skip to the feedback for their choice before continuing. This ensured a single unit contained all of the interactive pre-laboratory content making it easier to evaluate the impact. This unit is assessed through online quizzes (25% of the grade), six laboratory sessions that are assessed by a pre-laboratory quiz as well as a worksheet completed during the laboratory (25%) and a final exam (50%).

**Table 2.2: Data collection during 2017 and 2018**

<table>
<thead>
<tr>
<th>Semester</th>
<th>Number of Students Enrolled in CHEM1002</th>
<th>Time</th>
<th>CLA and CLSE Questionnaire</th>
<th>Feedback Survey</th>
<th>Interactive Pre-Laboratory Activity</th>
<th>Interviews</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Semester One, 2017</strong></td>
<td>255</td>
<td>Start</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>During</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>End</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Semester Two, 2017</strong></td>
<td>147</td>
<td>Start</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>During</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>End</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Semester One, 2018</strong></td>
<td>344</td>
<td>Start</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>During</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>End</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Semester Two, 2018</strong></td>
<td>70</td>
<td>Start</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>During</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>End</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The four laboratory sessions for which a pre-laboratory activity was developed were:

*Acids and Bases*: Students separate a mixture of benzoic and quinine based on their acid-base properties. This is done using a separatory funnel and is followed by a recrystallisation of the benzoic acid.

*Reduction of Benzophenone to Diphenylmethanol*: Students use sodium borohydride to reduce benzophenone to diphenylmethanol under reflux before recrystallising the diphenylmethanol product.

*Synthesis of Esters*: Students synthesise two esters by different methods. Isoamyl acetate is synthesised from isoamyl alcohol and acetic acid and aspirin is synthesised from salicylic acid and acetic anhydride.

*Purification of Esters*: Students do a distillation to purify the previously synthesised isoamyl acetate and a recrystallisation to purify the aspirin.

The two laboratories, for which new interactive pre-laboratory activities were not made were:

*Molecular Models*: Students practice using molecular model kits. No interactive pre-laboratory activity was made for this laboratory due to the different nature and the high in-laboratory level of student-demonstrator interaction.

*Aromatic Nitration*: Students do a nitration of acetanilide. No interactive pre-laboratory activity was made for this laboratory because there was already an interactive YouTube pre-laboratory video\(^1\) that could be compared by the students in the feedback surveys with the interactive pre-laboratory activities made using Adobe Captivate 9.

---

\(^1\) The link for this video is: https://www.youtube.com/watch?v=LygPVAnfVBc&feature=youtu.be
2. 2 Methodology

This chapter outlines the research approach taken. First there is a discussion of the action-research framework. This is followed by a discussion of mixed methods, surveys, interviews, case studies and the statistical analyses performed. Approval to conduct this research was provided by the University of Western Australia with reference number RA/4/1/9011.

Action Research

Action research is a well-established method used in education research to develop and evaluate interventions (McNiff & Whitehead, 2010; Mills, 2000). Mills (2000) describes the stages of action research as: deciding on an area of focus, collecting data, analysing those data, developing an intervention based on those data and collecting and analysing new data to evaluate the intervention. This leads on to further development and re-evaluation until the researcher is satisfied.

This study roughly followed an action research structure. First an area of focus was decided on: the impact of pre-laboratory activities on students’ CLA and CLSE. Then a literature review was undertaken, an updated version of which is presented in chapter one. Following which, data about students’ CLA and CLSE were collected, analysed and used in the development of an intervention. This is discussed in more detail throughout the results chapters. In this study, more data were then collected about students CLA and CLSE to evaluate how much of an impact the intervention had made. Additional data were also collected in the form of feedback surveys to be used in the ongoing development and improvement of the pre-laboratory activities.
Mixed Methods

A mixed methods approach was used in order to investigate students’ negative feelings about laboratory work in a first-year university chemistry unit. This type of approach was also used to investigate pre-laboratory activities as a possible intervention to address these negative feelings. A mixed methods approach is one that collects, analyses and reports both quantitative and qualitative data (Creswell, Plano Clark, Gutmann, & Hanson, 2003). As part of this research project a survey was developed to quantitatively investigate the effect of the pre-laboratory activities on students’ anxiety and self-efficacy. As discussed in the literature review little has been done to quantify the potential impact of pre-laboratory activities in the affective domain. Qualitative data were collected in interviews with students.

The type of mixed methods design used in this study was a mixture between a triangulation design, also known as a concurrent or parallel design (Creswell, 2002), and an explanatory design.

As in a triangulation design, the quantitative and qualitative data were used together to develop a more complete understanding, to validate the results and to benefit from the strengths of both types of data (Creswell, 2002). As in an explanatory design the qualitative data were collected after the quantitative data to develop a better understanding of the quantitative results previously obtained (Creswell, 2002). This type of research is also known as a two-phase model.
Surveys

Two types of written responses were conducted in this research project. The first type was a questionnaire based on Bowen’s (1999) CLAI, that had additional questions about other aspects of laboratory work and about students’ CLSE. It was called the Chemistry Laboratory Anxiety and Self-Efficacy Questionnaire (CLASEQ). The second type of written response consisted of feedback surveys, like those used by Spagnoli et al. (2017), to evaluate the students perspectives of the pre-laboratory activities. All questionnaires and surveys can be found in the appendices (Appendices: C, G, H, J and L) and a more detailed description of the development of the survey to measure CLA and CLSE can be found in chapter three, section two.

The CLASEQ was delivered in a longitudinal manner with data collected at the start and end of each semester, allowing for trends to be observed. Considering each survey individually allowed for descriptions on individual variables and relationships (Borg & Gall, 1989). The feedback surveys were cross-sectional in design, being delivered at just one point in time. As much as possible leading questions were avoided, as were questions that were complex, used jargon, or that could be offensive as recommended by Cohen and Manion (1989).

The changes in the feedback surveys from one semester to another were made in response to literature findings. For example, in semester one 2018 students were asked what was important to them in the laboratory as control-value theory emerged from the literature as a potentially relevant framework to investigate. Changes were also made to complement data previously collected. For example, in semester two 2018 students who completed the pre-laboratory activities were asked why they did so, in comparison with semester two 2017, in which, reasons for noncompletion were investigated. Due to concerns about the lengths of the surveys, questions were not continuously added, rather, questions that had already been answered in previous semesters were replaced.
Interviews

As with the surveys, the questions posed to the students during interviews can be found in the appendices (Appendices: I, K, M). Few students volunteered to be interviewed and so selection criteria were irrelevant. Instead, all students who were willing were interviewed. The interviews were conducted and transcribed by the student conducting the research study and all identifying information was removed from the transcriptions prior to them being shared with any staff involved in the marking of the unit. All case studies presented in this thesis are done so under pseudonyms.

As put by Burns (1994) an advantage of interviews is that “probing may be used to elicit more complete responses.” However, Burns (1994) also notes that there are disadvantages to interviews such as the time needed to conduct them and the resulting limit to the number of respondents who can be interviewed. Additionally, the interviewer may unintentionally influence the responses of participants. It should be noted that in this study the interviewer was the primary researcher and had no formal training in interview techniques.

While higher participation rates are noted as an advantage of interviews (Borg & Gall, 1989) this was not seen in this study with many mores students competing the surveys than volunteering for interviews. Nevertheless, the advantages of the qualitative data remain, in that, rich description was obtained and that students could be asked not only about their feelings but also about their understanding of where those feelings originated from (Creswell, 2002).
Case Studies

Thirteen students were used as in-depth case studies. The data used to form these case studies came from the surveys and interviews. While not necessarily representative, case studies give unique insight into the experiences of individuals.

The case studies constructed in this research project can be classified as psychological and interpretive according to Merriam (1988). They are psychological in that they focus on individual students, and use “‘concepts, theories, and measurement techniques from psychology in investigating educational problems,’” (Merriam, 1988, p. 25). This type of case study is also called “instrumental” (Creswell, 2002; Merriam, 2009). They are interpretive in that they not only provide rich descriptive data, but also can be “used to develop conceptual categories or to illustrate, support, or challenge theoretical assumptions held prior to the gathering of data,” (Merriam, 1988, pp. 27-28). Finally, they were used in this study as a means of triangulating the results of the surveys.

Advantages of a case study design is that it, as put by Merriam (1988) they “offer insights and illuminate meanings that expand its readers’ experiences. These insights can be construed as tentative hypotheses that help structure future research; hence, case study plays an important role in advancing a field’s knowledge base.” Disadvantages of case studies include: the time taken to collect the data, the inevitable length of the presented results, the tendency of either researchers or readers to generalise non-representative data and the opportunity for subjective bias in selecting the data to present.

Internal validity for the case studies was mainly reliant on the triangulation with the surveys. It also involved asking participants confirm whether an understanding of what they said was accurate, a process referred to as a “member-check” by Merriam (1988). While the case studies were not generalisable, they were instead used to generate “working hypotheses” as recommended by Cronbach (1975) and Merriam (1988).
Statistical Analysis Using SPSS

Analysis of the data was performed using the SPSS software. Likert scales provide ordinal data, and there is debate about whether a parametric approach can be used for such data (I. E. Allen & Seaman, 2007; Jamieson, 2004). There are examples that promote a parametric approach even when the data do not meet the assumptions of normal distribution or non-homogenous variances (Norman, 2010). However, in this study the conventional non-parametric approach was adopted as recommended by Pallant (2013).

In 2017 as ethics approval had not been obtained to collect student numbers and thus the data could not be paired. A Mann-Whitney U test, the non-parametric equivalent of the independent t-test, was used to examine the unpaired samples of non-parametric data. The purpose of the Mann-Whitney U test is to determine whether a significant difference exists between two populations. It provides measures of the significance ($p$ values) and size ($Z$ values) of any differences.

Values of $r$ (a more common measure of effect size) were obtained by dividing $Z$ by the square root of the sample size, $(N)$ (Pallant, 2013). To determine the correlation between constructs, such as CLA and CLSE, Spearman’s Rho was calculated. Spearman’s Rho, also known as the Spearman Correlation Coefficient, is also a non-parametric measure.

In 2018, ethics approval was obtained to collect student numbers for use as identifiers. Therefore, a Wilcoxon Signed-Rank test, a non-parametric approach for paired samples, was used to determine whether there were significant differences between samples of data. Spearman’s Rho was still used to test for correlations between variables.
Methodology Summarised

The development of the pre-laboratory activities in this study follows an action-research methodology. Firstly, a review of the available literature was conducted (chapter one). Then, data were collected to investigate the specific context in which the intervention would be implemented (chapter three). These data were analysed and used to inform the development of the intervention (chapter four). After each implementation of the intervention, feedback was collected, analysed, and used to make improvements before re-evaluation (chapters five and six). The evaluation of the pre-laboratory activities was performed using a mixed-methods approach. This approach combined quantitative survey data about students CLA, CLSE, and their perspectives of the pre-laboratory activities, with qualitative interview data, from which case studies were constructed.
3.0 STUDENTS’ CHEMISTRY LABORATORY ANXIETY AND SELF-EFFICACY PRIOR TO AN INTERVENTION

3.1 Introduction

This project focussed on the development and evaluation of interactive pre-laboratory activities as an intervention to reduce students’ CLA and increase their CLSE. In keeping with an action research approach, data were collected prior to making an intervention. The collection and analysis of these data could then inform the development of the pre-laboratory activities. This chapter discusses the development of the questionnaire used to collect these data, the statistical analyses performed, and the results of those analyses.

3.2 Development of the CLASEQ

Firstly, in order to gain a more detailed understanding of the elements that contribute to CLA, a questionnaire was developed based on the Chemistry Laboratory Anxiety Index (CLAI, Bowen, 1999). The questionnaire developed for this study will be referred to in this thesis as the Chemistry Laboratory Anxiety and Self-Efficacy Questionnaire (CLASEQ). It can be found in Appendix C, along with the participant information form (Appendix A) and participant consent form (Appendix B).

The CLASEQ included questions about an additional three possible aspects of chemistry laboratory work that may contribute to CLA which were not included in the CLAI. They were asking for help from a demonstrator, interpreting their data, and answering assessed questions. Students were also asked about their CLSE with respect to aspects of the laboratory work that were expected to contribute to CLA. Finally, the survey included questions about the students: 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 biasing the results (Teclaw, Price, & Osatuke, 2012).
Justification of the Differences between the CLAI and the CLASEQ

The additional aspects of laboratory work considered by the CLASEQ but not the CLAI were answering assessed questions, interpreting their data, and asking for help from a demonstrator. Grades are important to students (DeKorver & Towns, 2015; Seery, 2017) and are therefore, an important aspect to explore. This was achieved by asking students how anxious they were about answering assessed questions in the laboratory, and how well they thought they were able to answer assessed questions in the laboratory.

Questions were also added regarding students’ anxiety and self-efficacy about interpreting data. According to Bloom’s taxonomy, interpreting data is a higher level of thinking than recording data (Adams, 2015), and therefore is expected to impose a higher cognitive load, be more difficult and therefore, possibly, be something students have lower self-efficacy about. Concern has been expressed over the impact of cognitive overload on students’ learning in the laboratory (Hubacz Jr, 2004), thus it was of interest to investigate whether students were anxious about this cognitive task.

The questions about asking for help from a demonstrator were included not only for the benefit of students who may feel anxious about or lack self-efficacy about asking for help, but also for the benefit of the laboratory coordinator. If one or more of the 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.

Students were also asked about how aversive they found their prior experiences in learning chemistry as aversive experiences can create anxiety about similar future experiences (Locker, Shapiro, & Liddell, 1996) Furthermore, prior experience has been shown to impact students’ CLSE (DeKorver & Towns, 2015). However, regular experience can, over time, create more realistic expectations (Arntz, Van Eck, & Heijmans, 1990).
3.3 Analysis of the Results from the CLASEQ

The CLASEQ was distributed using Qualtrics, a survey hosting website. The results were collected anonymously, and statistically analysed using the SPSS software. Due to the ordinal nature of the data, comparing mean values was an inappropriate method of determining the significance of observed changes (Pallant, 2013). Instead, a Mann-Whitney U test was used to test for significant differences between students’ anxiety and self-efficacy about aspects of the laboratory at the start and end of the semester. Spearman’s Rho was calculated to analyse the correlation within sets of data between anxiety and self-efficacy for each aspect of laboratory work. A comparison of means and medians was used to identify and rank the aspects of laboratory work that caused students the most anxiety. This comparison was also used to rank the aspects of laboratory work with respect to student’s self-efficacy.

3.4 Students’ CLA and CLSE about Specific Aspects of Laboratory Work

Figure 3.1 shows the levels of CLA and CLSE reported by students about various aspects of laboratory work. For means and standard deviations see Appendix D. There is an observable trend that students reported 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 impacted students’ grades. This provided further evidence that students greatly value the grades they achieve in their studies (DeKorver & Towns, 2015; Seery, 2017).
Aspects of Chemistry Laboratory Work that Students have Least Self-Efficacy About:

The opposite was true for self-efficacy. Students reported lowest self-efficacy about completing the work in time. They also reported lower self-efficacy about the cognitive aspects of laboratory work (interpreting data, answering assessed questions) than the psychomotor aspects (working with chemicals, working with chemical equipment and recording data). They reported highest self-efficacy regarding the social aspects of laboratory work (working with other students and asking for help from a demonstrator).

Again, means and standard deviations for self-efficacy are available in Appendix D of the supplementary information. The expected inverse correlation between chemistry laboratory anxiety and chemistry laboratory self-efficacy about specific aspects of laboratory work was clearly visible in the data collected.
3.5 Changes in Students’ CLA and CLSE from the Beginning to the End of a Semester

Figure 3.2 shows how anxiety and self-efficacy changed from the beginning to the end of the semester. Given the potential for mastery experiences in the laboratory sessions, it is not necessarily surprising that a significant increase in self-efficacy was observed. Furthermore, given the inverse correlation between anxiety and self-efficacy it was not surprising that there was a significant decrease in anxiety. Using Mann-Whitney U, analysis it was seen that the increase in self-efficacy for each aspect of laboratory work was significant at the $p \leq 0.001$ level for each aspect. 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 respectively) are available in Appendix E. While this increase in self-efficacy is inconsistent with the decrease in self-efficacy seen during work on the prepare, do review model (Spagnoli et al., 2017) it is consistent with other previous work (Boddey, 2012).
Figure 3.2 A) Aspects of anxiety related to the chemistry laboratory at the start (upper bar of pair, *N* = 178) and end (lower bar of pair, *N* = 133) at the start and end of semester one 2017. B) Aspects of self-efficacy related to the chemistry laboratory at the start (upper bar of pair, *N* = 178) and end (lower bar of pair, *N* = 133) at the start and end of semester one 2017.

3.6 Correlation Between Students’ CLA and CLSE

Spearman’s rho correlation values, as well as *p* values, can be found in Appendix F. The correlations between self-efficacy in one aspect of laboratory work and self-efficacy in another aspect were, on the most part, positive and significant. For example, students who were had high self-efficacy about their ability to work well with chemicals also has high self-efficacy about their ability to record data, though there was variation in the strength of these correlations.
CLSE was significantly inversely correlated with CLA for each aspect of laboratory work. For example, students who had high CLSE about their ability to work well with chemicals were also less anxious about working with chemicals. Generally, the strongest correlation for self-efficacy about a specific aspect of laboratory work was with anxiety about that aspect. For example, self-efficacy about working with chemicals was more strongly correlated with anxiety about working with chemicals than anxiety about other aspects of laboratory work (for exceptions see Appendix F). The correlation between self-efficacy and anxiety for each aspect of laboratory work was significant at the $p \leq 0.001$ level for each aspect, 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 follows that being able to work well with chemicals may only give some reassurance. In contrast, for an aspect such as recording data, where the concern is only with ability to perform the task, a stronger inverse relationship between CLA and CLSE would be expected.

3.7 Students’ CLA, CLSE, and Their Expectations about Grades and Aversiveness

Students were asked to rate how aversive their most-recent prior chemistry education experiences 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. That is, students who thought their prior experience was more aversive expected the current unit to be more aversive. Additionally, expected aversiveness was more strongly correlated than prior aversiveness with high anxiety and low self-efficacy. This is logical and implies students to some degree understood what was meant by “aversiveness. However, due to concerns that not all students would understand what was being asked, this question was replaced in 2018 with a question about how enjoyable students had found their prior experiences.
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 (which were only significant at the $p \leq 0.05$ level) and anxiety about working with other students for which the correlation with expected aversiveness was not significant. This implies that prior aversiveness is not the only predictor of expected aversiveness but, given the strong correlation between the two, it seems likely that more aversive prior experiences detrimentally effect students’ self-efficacy and anxiety.

Expected aversiveness was also correlated with expected grades. Students who rated their prior experience as more aversive expected lower grades. 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, finishing in time, asking for help, interpreting their data and answering assessed questions. Students who expected a higher grade generally also desired a higher grade than those who expected a lower grade.

### 3.8 Summary

By developing a new questionnaire, based on the CLAI (Bowen, 1999), the CLASEQ, it was found that students were most anxious about: completing the work in time, answering the assessed questions and interpreting the data they collected. These were also the aspects of laboratory work regarding which they had least self-efficacy. In addition, there was a significant inverse correlation between CLA and CLSE for each aspect of laboratory work. Finally, students reported significantly lower CLA and higher CLSE at the end of the semester than at the start. The data were then used to inform the design of the pre-laboratory activities as will be discussed in the next chapter.
4.0 DEVELOPMENT OF AND FEEDBACK ON THE FIRST GENERATION OF PRE-LABORATORY ACTIVITIES

4.1 Introduction

Having identified which of the aspects of chemistry laboratory work considered by the CLASEQ students had highest CLA and lowest CLSE about, a set of pre-laboratory activities were developed as an intervention to reduce CLA and increase CLSE. This chapter describes the development of the first generation of interactive pre-laboratory activities. It also includes a discussion of the student feedback collected via surveys and interviews.

4.2 Development of the First Generation of Pre-Laboratory Activities

For each laboratory session the main cognitive and psychomotor skills involved were identified. Having identified what would be required of students, the pre-laboratory activities were developed to:

a) develop a basic schema of the theory,

b) model the relevant skills and

c) provide opportunities for students to answer non-assessed questions to gain mastery experiences in answering the type of questions they would be asked in the laboratory.

Adobe Captivate 9 software was used to allow for this combination of content and interactivity. Each pre-laboratory activity had an introductory slide with the learning goals for the laboratory and the pre-laboratory (Fig. 4.1). This was in response to literature findings that there is a mismatch between student goals and learning outcomes when it comes to laboratory sessions (Hensiek et al., 2016; Reid & Shah, 2007). In contrast to the teaching goals, students’ goals tend to be assessment focussed (DeKorver & Towns, 2015, 2016). Clarifying the expected outcomes has been found to reduce misalignment between student and educator goals (Reid and Shah, 2007).
Learning Goals

- Labs are a great opportunity to learn practical chemistry skills and to apply your chemistry knowledge.
- This pre-lab is designed to introduce you to the practical skills you’ll be able to practice in the lab and to get you thinking about the theory behind what you’ll do in the lab.
- This will help you manage your time in the lab and answer the assessed questions.

Figure 4.1: Slide clarifying learning goals in pre-laboratory activity.

The pre-laboratory activities assumed that students had not done any prior research and so began by developing a basic understanding of the theory behind the laboratory (Fig 4.2).

Identifying Acids and Bases

- These are the structures of benzoic acid and quinine:

  ![Benzoic Acid Structure](image1)
  ![Quinine Structure](image2)

- Which one is benzoic acid?

Figure 4.2: Example of an interactive slide developed to teach basic theory.

The pre-laboratory activity then got students to think through the theory in more detail with a specific focus on understanding the aspects of the theory that would be assessed.
(Fig 4.3, 4.4). However, students were not made aware of what would be assessed to prevent rote learning.

**Figure 4.3**: Example of an interactive slide developed to teach more specific theory.

**Figure 4.4**: Example of a slide explaining the theory of an experiment.

Images and videos taken specifically for these pre-laboratory activities were used to provide students with the ability to visualise the practical techniques given that some of the equipment may have been unfamiliar. During the pre-laboratory activity students had the techniques modelled and explained to them. They were then given opportunities to test their understanding of the content using the interactive features (Figure 4.5).
Due to the high anxiety reported by students about being able to complete the work in time, time management tips were incorporated throughout the pre-laboratory activities (Fig 4.6).

Step-by-step instructions may lead to a cookbook approach whereby students do the practical work without cognitive engagement (Carnduff & Reid, 2003). However, at this stage, students had already thought through the laboratory. A check-box summary was given to model breaking down complicated instructions into manageable chunks.
4.3 Evaluation of the Second Generation of Pre-Laboratory Activities: Feedback Survey Results

After the first interactive pre-laboratory activity, 118 students (80.3%) responded to the in-lab pen and paper feedback survey (Appendix J). 86 said they had completed the activity and 32 said they had not. After the final pre-laboratory activity, 68 students reported in an online survey (Appendix H) that they had completed the activity, and 14 reported that they did not complete the activity. The reasons given for non-completion at the start and end of semester two 2017 are given in Figures 4.8 and 4.9.

Figure 4.8: Reasons given for not completing the first pre-laboratory activity at the start of the semester (N = 32)
Figure 4.9: Reasons given for not completing the pre-laboratory activity at the end of the semester ($N = 14$)

In response to the high number of students who were unaware of the pre-laboratory activities, at the start of subsequent semesters, emails were sent to students to inform them of the existence of this resource. It is recommended that if pre-laboratory activities are developed, then students are explicitly made aware of their existence and where to find them. It is also recommended that educators who develop pre-laboratory activities seek students’ feedback about how the activities work on a variety of devices. Any technical difficulties identified ought to be fixed as they contribute to user-friendliness and quality of the resources, which is important in designing e-learning resources (Almala, 2007; Winkler-Prins et al. 2007).

Of the students ($N = 85$, 57.8% of the cohort) who completed the pen and paper survey (Appendix G) after the first interactive pre-laboratory activity: 88% reported that the videos worked, 81% of students thought that the pre-laboratory activities were interesting, 86% thought the pre-laboratory activity helped them to prepare for the practical session, and 90% said they would do the pre-laboratory activities again. 76% of students said the activities were somewhat or very helpful.
It is worth noting that giving three degrees of agreement or disagreement tended to result in many responses that were very neutral. Figure 4.10 shows students’ responses to questions in the initial feedback survey about helpfulness, confidence and anxiety. Given the number of students who said they would do the pre-lab again, there were a surprising number who said that they found the first pre-lab to be “not at all” helpful, and very few who said that they thought it was “very helpful”. It is worth noting, however, that most of the students found it to be “somewhat helpful”. This left an amount of ambiguity to be further investigated in the following semesters as the second and third generations of pre-laboratory activities were evaluated.

![Figure 4.10 Students’ perceptions of the helpfulness of the pre-laboratory activity, and of their confidence and anxiety about the laboratory (N = 85)](image)

In the final survey, most students agreed that the activities stimulated their curiosity, that they were encouraged to learn by the activities, that they felt confident using the knowledge they had acquired to solve problems in the practical session, and that the activities left room for them to make their own discoveries. 73.5% of students in this end of semester survey agreed or strongly agreed that preparing for the laboratory made them less anxious about the practical session. 70.6% of students agreed or strongly agreed that doing the interactive pre-laboratory activities made them less anxious about the practical session. In contrast only 47.1% of students agreed or strongly agreed that doing the online quizzes made them less anxious about the practical session.
Of the comments received from students who did the interactive pre-laboratory activity the repeated themes were navigation issues, needing more time on each slide and finding the mini-games annoying rather than helpful.

When asked what they would add, four students said nothing, five mentioned wanting more information, and three asked for harder questions. When asked what they would remove, seven students said nothing, three students said they would remove the puzzle game and one said they would remove the videos. When asked what they would change, two students mentioned compatibility issues, two wanted shorter loading times, three said they wanted the videos to work, and four mentioned fixing other technical issues.

While it was expected that the incorporation of gaming elements would be appealing to students, several comments were made to the contrary, for example “what… was that puzzle game, I mean we are university students, also it draws attention to solving of the puzzle and away from the information provided in the picture”. This indicates that problems may occur if gaming elements are seen as patronising or take too long. The mini-games were removed from the next generation of pre-laboratory activities for this reason. Additionally, the rest of the feedback collected was also incorporated into the development of the next generation.

*Evaluation of the First Generation of Pre-Laboratory Activities: Perceived Difficulty*

As self-efficacy is related to perceived difficulty (Bandura, 1977) students were also asked about their perceptions of how difficult the practical laboratory sessions would be after completing the pre-laboratory activity. It was found that students reported having thought the laboratory sessions would be significantly harder before they did the pre-laboratory activities than after ($p < 0.001$). It was also found that students thought the laboratory sessions would have been significantly more difficult without the pre-laboratory activities ($p < 0.001$).
Evaluation of the First Generation of Pre-Laboratory Activities: Productive Worry

Given that worry is the cognitive dimension of anxiety, and that worrying can be productive or unproductive (Leahy, 2002), it was of interest to investigate the nature of students’ worrying.

From the data collected, it was seen that students reported worrying more before the laboratory than after (Figures 4.11 and 4.12). Worrying before the laboratory can be productive as there is the opportunity to channel that worry into preparation. Worrying after the laboratory is unproductive as no action can be taken to change what has happened. If students think about whether the laboratory is likely to go well this may be helpful in curbing excessive worry, provided their thinking is rational, which cannot be guaranteed. Therefore, thinking about how to ensure the laboratory goes well fits better with the idea of productive worrying as productive worrying involves thinking about which situations that are likely to occur, and what actions are likely to make a positive difference (Leahy, 2002).

**Figure 4.11: Students’ perceptions of how they worry before the laboratory.**
Figure 4.12: Students’ perceptions of how they worry after the laboratory.

The data were analysed to see if a significant correlation existed between how students worried and pre-laboratory completion. However, no significant difference was seen between students who completed the pre-laboratory activity and any specific kind of worrying. Future work might consider how to use pre-laboratory activities to encourage productive worrying. It may also be of interest to investigate how to encourage students to channel feelings of anxiety into productivity, like for example, preparing for the laboratory by competing the pre-laboratory activities.

4.4 Evaluation of the First Generation of Pre-Laboratory Activities: Case Studies

Students were invited to participate in interviews in order to obtain more detailed qualitative data. First, three students participated in a think-aloud style interview as they worked through one of the pre-laboratory activities for the first time (Interview One). Then, two of these students came back after the corresponding laboratory session for a more structured interview (Interview Two). The prompts for Interview Two are included in Appendix I.
The data collected in the interviews are presented below as a series of case studies. Due to restrictions in the ethics proposal, no student identifiers were collected and the interviews could not be linked back to survey responses for semester two 2017.

**Sophie – Interview One**

Sophie only participated in one interview. She explained during the interview that she was doing both chemistry units in the same semester and had limited experience in a laboratory setting.

“I’m doing 1002 and 1001 so I’ve not really had any other labs before. The first few were really stressful but I’m doing ok now.”

This was consistent with the data collected in the surveys, which showed students generally had higher anxiety at the start of the semester.

Sophie said that she thought the interactive pre-laboratory activity helped her to prepare because it showed her how to set up the equipment, which was something that she tended to be stressed about. She also said that she thought it was helpful that the pre-laboratory activity made reference to the earlier laboratory sessions, which gave a frame of reference for how long things ought to take. She explained that because she hadn’t done much laboratory work before that was really helpful as:

“The time frame is the big thing.”

Which is consistent with the survey results which showed that finishing the work in time was what students were most anxious about.

Sophie agreed that she had higher self-efficacy at the time of the interview than at the start of the semester and attributed that to the fact that the previous laboratory (molecular models) …
“...was quite a relaxed lab, and I feel like I was able to ask a lot of questions and it helped me visualise it a lot more. So that helped me understand the whole concept a lot better.”

She agreed that having less time pressure meant she could actually learn more in the laboratory and added:

“I knew I had to ask, not just about the questions that were right there, but about what they meant in the grand scale of this topic.”

The connection she made between having time and developing a contextualised understanding of the topic may support the idea that time pressure can interfere with students’ ability to connect what they are doing in the laboratory to the rest of the unit content. This connecting of information to a larger body of knowledge is the process of schema development, which is known to be impaired by a high cognitive load (Winberg & Berg, 2007).

Sophie also talked about the helpfulness of the pre-laboratory quizzes used in CHEM1001. Specifically, that getting the feedback from them was helpful because they didn’t just give a score but explained why an answer was correct or not. As a result of the requests made by both Sophie and other students, more detailed feedback was something that was increasingly added into the interactive pre-laboratory activities as they were developed.

Other things that Sophie said were helpful to her included being able to see parts of the experiment being done and working with a partner.

“reading through what to do, is very different from seeing it... Now I know exactly when I go in what steps I’ll be doing.”

“...and because I was working with someone else in that one it helped a lot”
Rachel – Interview One

Rachel was an international student from Indonesia. In the first interview she referenced this explaining that:

“I used to do labs in my country [Indonesia], in my high school, but not as intimidating as here, maybe because we worked in groups.”

As with Sophie, working in a group made her less anxious. However, she indicated a lack of self-efficacy stating that she was bad at chemistry.

While working through the pre-laboratory activity she admitted that she was just guessing some of the answers. This affirmed the need for more detailed feedback, even for correct responses, as students may guess correctly. This may increase students’ self-efficacy in the short-term but would not help them gain the kind of mastery experiences in the laboratory that are expected to lead to long-term improvements in self-efficacy.

One other comment Rachel made in the first interview was that:

“…[for] the last lab (aromatic substitution), the video on YouTube was pretty much good as well”

The video she was referring to, was the YouTube video with links in it. The video allowed students to answer three different questions during the video. Depending on the choice made by the student the video would play out differently. This format severely limited the interactivity, so it was interesting that Rachel saw the two as fairly equivalent.

Rachel – Interview Two

In her second interview, after the laboratory session associated with the pre-laboratory activity discussed in the first interview, Rachel mentioned three things that she had found stressful.
“Sometimes we can’t really hear what [the demonstrators] are saying... which is kind of stressful.”

“The product, not making that was really stressful, but all of the theory was there.”

“It was intimidating... probably because of the time... if I got a good preparation then I’ll do really good.”

This supports the idea that “laboratory anxiety” and “laboratory self-efficacy” are not simple constructs, but that multiple sources contribute to feelings of anxiety and self-efficacy in the laboratory. Two broad categories for these sources are the psychomotor and cognitive aspects of laboratory work.

Rachel’s statement about preparation showed that she expected to do well when she prepared well. Therefore, preparing students for the laboratory may be a way to build their self-efficacy. The way in which she linked preparation to time pressure could reflect that time-pressure makes it necessary to work more efficiently and that preparation enables a student to work more efficiently.

Rachel went on to mention preparation many more times in the interview. Having stated that she did a lot of preparation before the laboratory she said:

“I think [the interactive activities are] really good because I got a really good mark after that.”

Indicating that at least part of the reason she spent time preparing for the laboratory was to get a good grade. This led to an interest in what students’ goals in the laboratory were, which was explored more in the next semester.

Rachel also related preparation to confidence and understanding.

“[The pre-laboratory activity] makes me confident about the lab and then I understand what we’re going to do, the practical stuff and the theory.”
She did, however, have some technical difficulties with the pre-laboratory activities.

“The last time, the pre-lab... I still cannot play the video... Some videos work some don’t... I tried reloading it several times.”

She also suggested that the pre-laboratory activities should not give all the information about the laboratory, but rather that they should be a starting point for students to do their own research. However, later on, she said that she thought giving more information than just what was assessed was ok as it enabled students to learn more. While these comments should not be generalised to a lack of concern about overloading students with information in the pre-laboratory activities, they were an interesting insight into how one student thought.

*Gilbert - Interview One*

Gilbert mostly made comments on the actual design of the pre-laboratory activity during the first interview. After mistaking the weighing boat for a round-bottom-flask he suggested that a useful feature might be a slide that listed the pieces of equipment students would use with each piece clearly labelled. This was added to future versions of the activities. Gilbert also commented on the back button, which had been recently added in to make navigation easier.

“The back button’s good cause the first time that’s what I thought would be useful.”

This indicated that he had been thinking about the design of the pre-laboratory activities prior to the interviews and encouraged the inclusion of free-response questions in future surveys.
Gilbert -Interview Two

In contrast to Rachel, who had issues with getting the videos to work, in his follow up interview Gilbert said that the pre-laboratory activity worked well and that he didn’t have any problems with it. He also said that there was no particular technical feature he thought needed to be added.

At multiple points Gilbert mentioned that the pre-laboratory activity had been useful because it made him more familiar with what he would be doing.

“It just kind of, helped step through it and I could remember- ‘oh yeah the condenser sets up like that,’ so, for the new stuff like the condenser, it made that slightly more familiar.”

“It made me more compelled to do the lab, and when you already know a bit about it, it’s easier to learn... you’ve already kind of familiarised yourself with it and you can actually think about it rather than just writing stuff down.”

Gilbert’s transition from talking about motivation to how easy it was to learn could indicate that the pre-laboratory activity reduced how difficult he thought the laboratory would be and that the effect of this was that he felt more motivated.

Like Sophie he emphasised the value of being able to see what the laboratory manual is describing.

“You can read about it in the lab manual, but you can’t visualise that and the pre-lab lets you visualise it.”
Additionally, he, like Rachel, talked about the need for better feedback.

“It only tells you for some of the questions correct or incorrect... [for some of them] if it’s false you got it wrong and then a little explanation why.”

He also noted that a correct answer did not necessarily mean that the student understood, and he said that if he had made a mistake, he wouldn’t have necessarily tried to work out why his answer was wrong.

“If you get it correct, maybe you guessed it... If I had done it on my own, maybe if I got one wrong, I’d just go ‘next’ and not really think about it.”

These reflections show the importance of explaining why an answer is correct or not. Partially to inform, and partially to prompt reflection which may otherwise not occur.

4.5 Summary

It is seen that a set of pre-laboratory activities can be developed using software such as Adobe Captivate 9 and distributed via an LMS. These can be evaluated using both surveys and interviews to collect quantitative and qualitative data. Whereas surveys provide more generalisable results, interviews produce a deeper insight into the experiences of a small number of students that can result in new questions and ideas. Both surveys and interviews can be used to gather recommendations from students that can be evaluated in light of the literature and potentially inform the improvement of available resources.

The main reason for non-completion at the start of the semester was that students were unaware of the resources available. At the end of the semester, the main reason given for non-completion was technical difficulties. Therefore, the first generation of pre-laboratory activities could be improved by addressing technical issues, including making sure the videos worked and improving the ease of navigation. They could also be improved by reducing the file size to minimise the time they took to load.
Students mostly completed the pre-laboratory activities and thought that the pre-laboratory activities were somewhat helpful for reducing their anxiety and increasing their self-efficacy, despite the technical issues. They thought the laboratory sessions would be more difficult before completing the pre-laboratory activities.

Students also thought the laboratory sessions would have been more difficult without them. The actual laboratory sessions were not altered whether students completed the pre-laboratory activities or not. Therefore, it its tentatively assumed that the difference made by the activities was to students’ perception of their abilities, in other words, to their self-efficacy.

Unfortunately, there was no correlation between pre-laboratory activity completion and productive worrying. Further research will be necessary to determine if the pre-laboratory activities could be changed to encourage productive worrying.

It is seen that Adobe Captivate 9 can be used to make interactive pre-laboratory activities, and generally students agreed that doing them made them somewhat reduced their anxiety and increased their self-efficacy. However, students needed to be more explicitly informed of the existence of pre-laboratory activities and the activities themselves needed to be improved technically. Therefore, work for the second generation of pre-laboratory activities mostly centred on addressing the technical issues as they were seen to be foundational to students’ engagement with the activities. Positive feedback from students helped determine which aspects of the pre-laboratory activities ought to be preserved.
5.0 DEVELOPMENT OF AND FEEDBACK ON THE SECOND GENERATION OF PRE-LABORATORY ACTIVITIES

5.1 Introduction

This chapter discusses the development of the second generation of interactive pre-laboratory activities and the student feedback collected relating to these activities. This feedback was collected in surveys and interviews. In both the surveys and interviews, students were asked not only about the pre-laboratory activities, but also about what they thought was important in the laboratory.

5.2 Development of the Second Generation of Pre-Laboratory Activities

Having discovered that technological difficulties were a prominent theme in both the survey and interview responses from students the focus of the development of the second generation of interactive pre-laboratory activities was on improving usability. As there was no apparent way to ensure that videos embedded in the Adobe Captivate 9 activities would work, all videos were removed. This was unfortunate as videos have been shown to be an effective way of modelling practical skills (Feltz et al., 1979). It is expected that the use of images instead of videos may have reduced the effectiveness of the pre-laboratory activities to model skills. However, this was considered preferable to videos that the students could not watch, and the resulting frustration or non-completion. More minor changes included removing the mini-games, due to their poor reception with some students, and the introduction of a navigation bar so that students could pause, skip or return to other slides. A final major change was the addition of a pre-laboratory activity for the aromatic substitution laboratory.
5.3 Evaluation of the Second Generation of Pre-Laboratory Activities: Feedback

Survey Results

The survey found in Appendix G was distributed after the last pre-laboratory activity. It was given as a pen and paper survey in an attempt to get a higher participation rate as this had proved effective in the previous semester. 56 of the 344 students enrolled (16.3%) at least partially completed the survey. 47 of these students provided demographic information. The respondents were 53.2% male and 46.8% female. 12.8% were mature-age, 17.0% spoke English as a second language, all of them were in their first semester at UWA and none had previously studied chemistry at a tertiary level. 47.8% intended on doing a level 2 chemistry unit. 71.7% of students wanted a high distinction but only 23.9% actually expected to receive one. 43.5% of students expected a distinction. 21.3% of students said they had chosen chemistry as a major.

There were two purposes to the survey. The first was to evaluate whether students thought the activities made them less anxious or more self-efficacious. The second was to collect information which could be useful in developing the third generation of pre-laboratory activities. This led to the inclusion of questions about what changes students thought would improve the pre-laboratory activities and which aspects of laboratory work students perceived to be most important.

Table 5.1 reports students’ responses to questions about the usefulness of the pre-laboratory activities. Around 80-90% of students agreed that doing the pre-laboratory activities made them less anxious about doing the laboratory and improved their self-efficacy about answering questions, completing the laboratory in time and doing the practical work. According to a Mann-Whitney U test there was a significant increase in how helpful the students thought the pre-laboratory activities were at reducing anxiety compared to the first generation ($Z = -2.61, p = 0.009$).
Table 5.1: Students perceptions of the helpfulness of the pre-laboratory activities (N = 54)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree (%)</th>
<th>Somewhat Agree (%)</th>
<th>Neither Agree nor Disagree (%)</th>
<th>Somewhat Disagree (%)</th>
<th>Strongly Disagree (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Felt Less Anxious After Doing Pre-Lab</td>
<td>37.1</td>
<td>44.4</td>
<td>7.4</td>
<td>11.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Felt More Confident (Answering Questions)</td>
<td>50.0</td>
<td>40.7</td>
<td>1.9</td>
<td>7.4</td>
<td>0.0</td>
</tr>
<tr>
<td>Felt More Confident (Time-Management)</td>
<td>38.9</td>
<td>46.3</td>
<td>11.0</td>
<td>1.9</td>
<td>1.9</td>
</tr>
<tr>
<td>Felt More Confident (Practical Work)</td>
<td>31.5</td>
<td>53.7</td>
<td>13.0</td>
<td>1.8</td>
<td>0.0</td>
</tr>
<tr>
<td>Received Adequate Feedback in Pre-Lab</td>
<td>18.5</td>
<td>38.9</td>
<td>20.4</td>
<td>22.2</td>
<td>0.0</td>
</tr>
</tbody>
</table>

In the free-response section of the survey there were four comments on remaining technical issues that were addressed in the development of the third generation of pre-laboratory activities. There were also a few comments about content such as, “teach glassware names.” These comments were incorporated in the development of the third generation of pre-laboratory activities.

Students’ Perceptions of the Importance of Aspects of Laboratory Work

As well as investigating students’ opinions about the activities and how they could be improved, students’ opinions about the importance of various aspects of laboratory work were also investigated. In light of control-value theory, it is expected that students will be anxious about an aspect of laboratory work, if they perceive doing it well to be important but lack self-efficacy (Pekrun, 2006). Therefore, identifying what students perceived as important was of interest in developing pre-laboratory activities to increase students’ self-efficacy, and reduce their anxiety. As the purpose of the feedback surveys was to collect information for use in the development of the activities, it was decided that they were an appropriate place to ask questions about what students thought was important.
Consequently, in the survey students were asked to indicate which aspects of laboratory work they thought were important (Table 5.2). Students were also asked to rank the relative perceived importance of the various aspects of laboratory work (Table 5.3). Relative importance was measured by asking students to rank the items from most important (1) to least important (8). Table 5.3 shows the median and average rank given to each aspect.

**Table 5.2: What aspects of laboratory work do students think are important? (N = 55)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Students Who Think Item is Important (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding What is Happening</td>
<td>92.7</td>
</tr>
<tr>
<td>Developing Laboratory Skills</td>
<td>87.3</td>
</tr>
<tr>
<td>Following the Procedure</td>
<td>83.6</td>
</tr>
<tr>
<td>Safety</td>
<td>81.8</td>
</tr>
<tr>
<td>Good Grade</td>
<td>76.4</td>
</tr>
<tr>
<td>Correct Product</td>
<td>74.5</td>
</tr>
<tr>
<td>Putting Theory into Practice</td>
<td>74.5</td>
</tr>
<tr>
<td>High Yield</td>
<td>63.6</td>
</tr>
</tbody>
</table>

**Table 5.3: How do students rank the comparative importance of different aspects of laboratory work (N = 53)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Median Rank</th>
<th>Mean Rank</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>1.00</td>
<td>3.09</td>
<td>2.69</td>
</tr>
<tr>
<td>Understanding</td>
<td>3.00</td>
<td>3.28</td>
<td>1.79</td>
</tr>
<tr>
<td>Good Grade</td>
<td>4.00</td>
<td>4.23</td>
<td>2.48</td>
</tr>
<tr>
<td>Putting Theory into Practice</td>
<td>4.00</td>
<td>4.60</td>
<td>1.84</td>
</tr>
<tr>
<td>Laboratory Skills</td>
<td>5.00</td>
<td>4.62</td>
<td>2.05</td>
</tr>
<tr>
<td>Following the Procedure</td>
<td>5.00</td>
<td>4.72</td>
<td>2.11</td>
</tr>
<tr>
<td>Correct Product</td>
<td>6.00</td>
<td>5.51</td>
<td>1.95</td>
</tr>
<tr>
<td>High Yield</td>
<td>7.00</td>
<td>6.06</td>
<td>1.95</td>
</tr>
</tbody>
</table>

Despite nearly 20% of students not reporting safety as important (Table 5.2), it was still the most highly ranked item in terms of importance (Table 5.3). Interestingly, gaining laboratory skills, following the procedure, getting the correct product, and getting a good yield, were all mentioned as the most important aspects of laboratory work by individual students during the interviews, despite being the four lowest-ranked items.
As is noted in the case studies presented later in this chapter, there seemed to be an overall consistency between students’ survey and interview responses. However, there were a few notable discrepancies which may benefit from further investigation and highlight the importance of mixed methods and triangulation of data. These discrepancies are discussed in the case studies but generally seemed to be about which aspects of laboratory work students thought were important.

Students’ understanding was supported by the pre-laboratory activities through the teaching of theory and development of schemas that could be used by students to make sense of the laboratory. The explanations given also aimed to help them connect the theory with what they were doing and seeing. Their development of laboratory skills and ability to follow the procedure were supported through the modelling of the techniques they would perform in the laboratory. Tips for doing this in a way that would result in getting the correct product in a good yield were also included. Safety issues were highlighted in the pre-laboratory to emphasise their importance but the actual work of keeping students safe fell on the laboratory session design, the demonstrators and the students’ own behaviour. Lastly, the pre-laboratory activities aimed to give students the information needed to help them think through the theory they would need to understand in order to answer the assessed questions and get a good grade. In these ways the pre-laboratory activities were already designed in such a way as to help students succeed at these aspects of laboratory work that they thought were important. As there were no clear items in questions six and seven which students generally thought were unimportant, none of the related content was removed in the next generation of pre-laboratory activities.

DeKorver and Towns (2015; 2016) suggest that students generally wanted to complete the laboratory requirements and get out of the laboratory early in order to feel good. They add that these affect-driven goals conflict with cognitive and psychomotor goals and may
be maladaptive and prevent meaningful learning. The survey results collected in semester one 2018 show students ranking understanding, a cognitive goal, above getting a good grade, an affect-driven goal. Additionally, getting a good yield or the correct product could also be seen as affect-driven goals, but were ranked lower. One important difference between the studies was that in the survey students were given a list and asked to rank them whereas in the work done by DeKorver and Towns (2015; 2016), students had to generate their own ideas. This may have contributed to the differences.

Additionally, there may be inconsistencies between what students think, how they behave and how they feel (Ostrom, 1969). Students may have answered what they perceived cognitively to be most important, but this may not be reflective of their affect-driven values or predictive of their behaviour.

Specific goals for the laboratory have been proposed in the literature (Carnduff and Reid, 2003; Reid and Shah, 2007). The goals of faculty members have also been investigated (Bretz, Fay, Bruck, & Towns, 2013) and compared with students’ goals (DeKorver & Towns, 2015; 2016). A misalignment between these goals has been consistently found (DeKorver & Towns, 2015; Hofstein & Lunetta, 2004). Laboratory teaching goals can be classified in different ways including practical skills, transferable skills and intellectual stimulation (Carnduff and Reid, 2003) or cognitive, psychomotor and affective goals (Bretz, Fay, Bruck & Towns, 2013; DeKorver & Towns, 2015; 2016).

While the type of data collected do not allow conclusions to be drawn about the effects of the pre-laboratory activities on what students perceived to be important in the laboratory, it is encouraging that 92.7% thought it was important to understand what was happening (cognitive) and 87.3% thought it was important to gain practical laboratory skills (psychomotor).
Space was given in questions six and seven for students to comment with other things they thought were important. Two students gave feedback in the “other” category. One said that it was important to have fun. This falls into the category of affective goals described by DeKorver and Towns (2015). A positive attitude towards chemistry is inversely correlated with anxiety (Kurbanoglu and Akin, 2010), but it was beyond the scope of the project to consider the impact of pre-laboratory activities on students’ attitudes as well as their anxiety and self-efficacy. The impact of pre-laboratory activities on students’ attitudes may, however, form the basis of a future study.

The other student who added something said, “helping each other”. The idea that inter-student support matters to students is supported by the literature (DeKorver & Towns, 2016) and the interview responses. Unfortunately, it was also beyond the scope of this project to investigate the social dynamics of the laboratory given that the pre-laboratory activities were designed to be completed by the students before the laboratory. However, as was seen in chapter three, generally students had highest self-efficacy and lowest anxiety about working with other students. This fits the control-value theory whereby, even if a person highly values an outcome, they will not be anxious if they have high self-efficacy (Pekrun, 2006).

Although interesting, neither students’ feedback had a direct bearing on the development of the following generation of pre-laboratory activities. However, the further investigation of the relationship between students’ goals and values in the laboratory and their anxiety, as well as the application of this in the development of interventions could indeed form the basis of an entirely separate study. Such a study should further investigate the relationships between students’ goals for the laboratory sessions, what they think is important, what they have high self-efficacy about, and what they are anxious about.
5.4 Evaluation of the Second Generation of Pre-Laboratory Activities: Case Studies

Another way in which feedback was collected was interviews. The interviews were conducted with six students over several weeks towards the end of semester one 2018. The interviews with students formed the basis of the following case studies. The prompts used are included in Appendix K.

Faith

Faith completed both CLASEQ surveys and the pre-laboratory evaluation survey. At both the start and end of the semester she reported less anxiety and higher self-efficacy than other students in general. She was a native English speaker and a mature-age student in her first year of studying chemistry at the University of Western Australia. She had previously studied chemistry at another university and rated the aversiveness of that experience as 5 out of 10. She expected this unit and the laboratory sessions to be similarly aversive (5 out of 10 for both). At the start of the semester she wanted and expected to get a high distinction. Whereas, at the end of the semester she only expected a distinction despite still wanting a high distinction.

In her interview Faith said that she liked doing the laboratory and working with chemicals. However, she clarified that she liked doing those things when there was not too much pressure. She also added that, when she was under pressure, she felt that she was more likely to make mistakes. Faith said she was most anxious about remembering what steps she needed to do and the order. She may have benefitted from learning to transfer that information from her working memory, where it would have increased her cognitive load, onto paper in her own words, if the laboratory manual was not sufficient.

Faith also mentioned that she always felt unsure if she was working fast enough and that she was anxious about that. This was consistent with her survey in which she said she was most anxious about completing the work in time.
Faith said that she was confident about most things. This is consistent with her high reported levels of self-efficacy across the semester. She added that as a mature-age student she felt that sometimes she lacked some of the assumed background knowledge. She said that lacking that knowledge had caused her stress at first but that the helpfulness of the demonstrators and her confidence to ask questions helped reduce this stress. She concluded that:

“\textit{I feel that now I’m pretty confident- like once I’ve done something, I feel pretty confident to do it again.}”

This is consistent with the idea that mastery experiences build self-efficacy (Bandura, 1977; Britner, 2008). For Faith it seems that the laboratory sessions provided enough mastery experiences to help her have high self-efficacy about repeating the things she learned in the future:

“\textit{...most of the skills that we’ve done I’d be quite happy to do again.}”

In her survey Faith said that all the aspects of laboratory work listed were important and rated getting the correct product as most important, followed by getting a good yield, getting a good mark, gaining laboratory skills, understanding what was happening, following the procedure, putting theory into practice and lastly safety. The fact that she ranked ‘getting the correct product’ and ‘getting a good yield’ above ‘getting a good grade,’ suggests that they held value for her outside of contributing to her mark.
Based on DeKorver and Towns’ (2015) work it is hypothesised that getting a good amount of the right product was something that made Faith feel good. The idea that making a good amount of the right product produces a good feeling which in turn effects students’ goals for the laboratory sessions would be interesting to investigate in a different study. In the interview, Faith said:

“I’m happy with a successful lab when I can do the experiment properly, but then also using good techniques... [at first] my procedure wasn’t that great in the sense that I probably didn’t get such a good yield... if I do get an accurate and good result- you know that you’re not taking shortcuts, but doing it properly and whatever, yeah that’s important to me... for me it’s also important that I can do the lab with a clear head space, that you’ve got that mental space to be able to still remain calm and know what’s going on and not be in a stressed state all the time.”

One interesting thing to note was that Faith used the quality and yield of her product to assess how well she had done the practical work. A contributing factor to the positive feeling students may experience when they get a good product, might be the sense of success and achievement of doing the work correctly. Other affective-domain goals are also present in her response: to remain calm and keep a clear head. The phrases ‘mental space’ and ‘clear head’ resonate with cognitive load theory and its assertion that an overloaded working memory interferes with the ability to think clearly and process information (Sweller, 1988).

Faith agreed that preparing for the laboratory sessions made her less anxious and that doing them increased her self-efficacy about laboratory work. In her interview she added that:
“The thing is that you just need to be as prepared as you can, some things that you can’t know beforehand and you just have to go in and do it, right?

Additionally, while a person can be prepared by seeing the skills modelled, for maximum improvement to self-efficacy the person must then actually do the task (Feltz et al., 1979). Faith’s comment represents this idea, that there is only so much that can be achieved through preparation alone. This is one reason to keep in mind that preparation materials are not an end in themselves but are part of a process that is continued when students apply what they have learned in preparation in order to gain experience.

While talking about the pre-laboratory activities, Faith reflected that the notes she’d taken during them helped her answer the questions in the laboratory. She did however note that they could be improved by extending the time the feedback appeared for, a suggestion which was incorporated in the next generation of pre-laboratory activities.

**Rhett**

Rhett was also mature-age student who spoke English as his first language. He was not in his first year at the University of Western Australia and had previously completed a chemistry unit there. He rated that unit as being 6 out of 10 on a scale of aversiveness but expected CHEM1002, both the unit as a whole and the laboratory sessions, to be a 5 out of 10 on that same aversiveness scale. At the start of the semester he wanted to get a distinction but only expected a credit. Interestingly both his reported CLA and CLSE were higher than the average at the start of the semester, despite a general trend that more anxious students had less self-efficacy. However, Rhett described himself as an anxious person and so it is possible that his anxiety was to do with his personality (trait) more than his lack of self-efficacy (state) (Spielberger, 2010). Rhett completed the survey at the start of the semester but not the pre-laboratory evaluation survey or the end of semester survey about anxiety and self-efficacy.
Rhett discussed an effect he’d witnessed in the laboratory, whereby students who lacked self-efficacy would be apprehensive about doing the work and would take longer. This was also mentioned by the demonstrator who was interviewed. Rhett mentioned seeing a large negative impact on students’ self-efficacy if their demonstrators weren’t supportive or made them feel stupid for not knowing something. Given that social influences affect self-efficacy (Britner, 2008) this is not surprising, and shows the importance of investigating how social factors may contribute to CLA and CLSE. This was done using the CLASEQ, which unlike the CLAI (Bowen, 1999), asked students about both their interactions with other students and with demonstrators.

Wanting to make sure he was doing things correctly led Rhett to want a very procedural-based pre-laboratory activity.

“...for me the only thing that really makes me afraid of the lab is probably the fear that I’m not doing everything right, and I’d love, in the pre-lab sense, to know that I’m going to be ticking off all the boxes with regards to following every step.”

In contrast with Dalgarno, Bishop, Adlong and Bedgood (2009), Rhett later added that familiarity with the laboratory, especially knowing where things were, was something he was concerned about.

The variety of students’ opinions on how to change the pre-laboratory activities is interesting. Because attention spans limit how long pre-laboratory activities can be not everything can be included, but different students want different things. One recommendation is that educators consider why students are making the requests. Another is to consider students’ opinions but make final decisions on what to include based on the literature about best pedagogical practice.
Rhett indicated strong positive feelings about the laboratory which may have helped with his anxiety.

“I’m always excited to be there. The idea of seeing so many of these concepts and things at work is just- yeah, fantastic and I really appreciate the opportunity for that… For me, the least difficult thing or the least-most anxiety-provoking thing to actually be thinking about is just doing the experiment, because I get happy thinking about it.”

Gain-framing, which emphasises the benefits of a behaviour, has been shown to be more persuasive for people in a negative affective state than loss-framing, which emphasises the risks or costs of avoiding a behaviour (Keller, Lipkus, & Rimer, 2003). For anxious students, a gain-framing intervention, that emphasises how interesting and fun a laboratory session can be may be an effective way to reduce negative feelings. However, this is well beyond the scope of this research project.

Rhett thought that it was important to connect theory and practice.

“I think it’s important that people bridge the gap between theoretical understanding, which is very, very vague and it’s really just a conceptual idea, and really see it working nuts and bolts, bricks and mortar in reality.”

He also thought that a successful laboratory was one in which he followed the procedure, got the expected product and answered the questions correctly. This was slightly surprising given the literature that critiques step-by-step methods for not helping students connect theory to practice. However, it is possible that Rhett hadn’t made that connection.
“I would just want to make sure that I’d done every step of what had been written in the lab manual, I’d just want to make sure that I’d done that step by step correctly. If I’ve done that, I can tick that off I’m happy, but I also want to make sure I get the result that’s described in the lab manual as well. That’s really what makes me happy, if I can answer all the questions and I get all the results that I’m supposed to get, I’m happy. However, if I don’t get the right colour or I don’t get the heat, or I don’t get the precipitate or whatever then I’m not happy.”

His repeated use of the word “happy” is intriguing as it relates to the affective domain. It also aligns with DeKorver and Towns (2015) findings that students often base their goals for a laboratory session primarily on what makes them feel good. They also suggest that affective goals can undermine cognitive and psychomotor goals which may explain why Rhett wanted to work through a procedure step by step even though he said he valued both theory and practice.

Finally, Rhett agreed that preparing made him less anxious. He said that he found knowledge to be the best way to dismiss fear. He also linked preparation with mastery experiences and a failure to prepare with a poor performance.

“[If you prepare] you should be able to weave your way through everything that’s going on in the lab... but it is integral to prepare. I find, if you’re not prepared and [don’t] know what’s going on you simply won’t be able to answer the questions.”
Daisy did not complete either of the surveys about chemistry laboratory anxiety and self-efficacy. Nor did she complete the interactive pre-laboratory activity evaluation survey. Therefore, none of her demographic information is available.

In the interview Daisy said she was most anxious about making the correct product, and not making mistakes in the procedure because the product was sometimes graded. She also said that she was anxious about finishing in time and the answering the questions on the worksheet. She expressed that she found it difficult to answer the questions and do the laboratory work at the same time. This may be explained by cognitive load theory.

Daisy said her goal for the laboratory session was to finish on time and get a good mark. This aligns with DeKorver and Towns (2015) findings that students were generally motivated to feel good by getting a good grade and often wanted to get out of the laboratory as soon as possible. However, given the large number of students who were anxious and lacked self-efficacy about finishing the laboratory sessions in time, Daisy’s desire to get things done quickly may be driven by a desire to finish on time rather than getting out early. However, as mentioned by DeKorver and Towns (2015) rushing laboratory work impedes meaningful learning from occurring, regardless of the motive.

DeKorver and Towns (2015) also noted that students desire to get a good grade and get out stood in conflict with other, more learning-directed, goals that the students had. Daisy expressed some of these more learning-directed goals when asked what else was important to her in the laboratory sessions:

“...being able to learn skills that I will be able to use later on, and learning them well, being able to do something with a good result.”
Jake

Jake was a first-year, native English speaker who had previously only studied chemistry at an upper high school level. He scored this experience as not at all aversive (1 out of 10). He expected CHEM1002 and the laboratory sessions associated with it to be more aversive (4 out of 10 and 2 out of ten respectively).

He wanted a high distinction but expected a distinction. At the start of the semester his anxiety was below average, and his self-efficacy was above average. By the end of the semester his anxiety had dropped even further and his self-efficacy had increased.

Jake said that what he liked least about the laboratory sessions was the time pressure. This fit with his survey response in which he said that what he was most anxious about was completing the work in time and answering the assessed questions.

In his survey Jake said that all aspects listed were important to him except getting a good yield. He ranked them as follows: safety, understanding what is happening, putting theory into practice, gaining practical laboratory skills, following the procedure, getting the correct product, getting a good mark, and least importantly, getting a good yield. This was consistent with his interview response where he said safety and the pre-laboratory introduction given by the demonstrators were most important to him. He said the reason the introduction was important because the demonstrators explained the relevant theory.

Jake agreed that preparation helped him feel less anxious. Like Rhett, he said this was because preparing helped him know and understand what he was going to do in the laboratory. He also agreed that preparing improved his self-efficacy which corroborated his survey responses. However, Jake’s goal for the laboratory was to…

“finish on time, to get a good yield, one that isn’t too high or too low, especially too high ‘cause that’s when you know you’ve really messed up something.”
Given that he said in his survey that getting a good yield was not important this was an attention-catching statement. Jake’s comment that a bad yield showed he had “really messed something up,” supports this idea that what he actually valued was following the procedure correctly, which was something he did indicate he thought was important.

Lastly, Jake suggested making more use of hints for students who got stuck, especially on calculations, in the interactive activities. This was considered and implemented in making the next generation.

Kyle

Kyle did not complete either of the CLASEQ surveys, so no data are available about his anxiety or self-efficacy. However, he did complete the pre-laboratory evaluation survey. He was a native English speaker and not a mature-age student. He was in his first semester at the University of Western Australia and had previously studied chemistry at an upper secondary but not tertiary level. He expected a credit but wanted a high distinction.

Kyle explained that he felt there were positive and negative aspects of having more freedom than he had in secondary school.

“It’s a good thing and a bad thing that we’re left [on] our own... at times you feel like you’re very lost and you’re trying to rush through a lot of the lab. Because you’d think three hours is enough but often times it’s not. There were times when I felt myself semi-panicking, especially when it went overtime. Like, I really wanted to go home, or I had some commitments that I had outside of uni, and I wasn’t going to make it, so I rushed through my work and then didn’t do as well as I hoped.”

The last comment about rushing in order to get out of the laboratory, and the subsequent negative impact of that, again agrees with DeKorver and Towns’ (2015) work, in that the goal of finishing the laboratory and leaving outweighed the goal of doing well.
This was consistent with Kyle’s survey responses in which he said getting a good grade wasn’t important to him in the laboratory. He also said that following the procedure was more important to him than understanding what was happening. Despite claiming that grades weren’t important to him Kyle did mention them in talking about what made him anxious in the laboratory sessions. He mentioned being anxious about making mistakes in the practical work and being behind with the lecture content and therefore not knowing what to do.

“In terms of most anxious, I would say, usually it’s the wet labs, ‘cause before the wet lab has started, I start to think about ‘oh what if I mix the chemicals wrong, what if I spill- ‘especially if you’re yield actually accounts for part of your grade, that’s sometimes when I start panicking. I kind of feel that if I haven’t caught up to the topic, if I’m a few lectures behind, that can also make me stress out a bit because I’m like ‘ok what am I doing?’ but usually the pre-lab videos and stuff, they tend to help me not stress, but even then especially if I’m quite behind it really does take quite a toll on how I feel I can do in the lab.”

Whereas other students talked about how preparing improved their self-efficacy, here Kyle described the opposite effect: a lack of self-efficacy due to not being prepared. Also, in his opinion the pre-laboratory activities helped but did not lead to him feeling that he did not need to attend or watch online his lectures.

In the interview Kyle said that in the laboratory he found the social support from the people working around him helped him to focus rather than stress. Also, he said that, when he broke a piece of glassware, knowing that he needed to get on and finish the laboratory session helped him to work productively rather than panicking.
“I actually broke the glass, that was when I panicked- I panicked but like, at the same time I had to think like ‘ok, I’m in the lab I’m in this situation, I have to be in the zone and I have to work effectively,’ so I cleaned the mess up, got the lab finished and that was, that was happy.”

One way of viewing this incident is as a mastery experience of sorts. Although Kyle made a mistake, the ability to carry on and finish in spite of that may have served to actually increase his self-efficacy about recovering from a mistake having done so previously.

Kyle said his main goal in the laboratory was…

“... to answer the questions and learn from it as best as I can, because I feel that once I do the lab and witness everything... I’m more engaged with whatever I’ve been learning... But at the same time, I also have the goal of wanting to get good grades essentially. I want to make sure that I’m answering everything correctly, that’s my main goal, and I want to make sure that I can actually take this lab and everything I’ve learned in that lab I can bring to the exam in a sense. I feel like that is my main goal.”

Again, this was not what he reported in his survey. This may suggest that students completing the survey underreported the importance of grades to them. Potentially thinking that they were giving the answers that the researchers wanted, though what was actually wanted was honesty.

Talking about the pre-laboratory activities Kyle said:

“Ok, the interactive [activities] helped me like crazy, that was the number one thing that I would [recommend] to reduce [a new first year student’s] anxiousness... there was occasional practice quizzes that you could do before in preparation for the lab and I feel like that would be another good option.
I wouldn’t exactly recommend going—like trying to skim through all the lectures before the lab because I feel like that makes it worse. So yeah, I reckon the interactive is the best way to go to reduce your stress, and maybe go through it more than once if you’re really feeling uncomfortable.”

In hindsight a good question to ask would have been why he thought skimming the lectures would make anxiety worse. One possibility is that it would be overwhelming and the worsening of any feelings of anxiety could be related back to cognitive load theory. The feedback that the interactive pre-laboratory activities helped prepare Kyle to do the laboratory work and reduced his anxiety was encouraging, despite not necessarily being representative. Kyle also said that he would recommend that an anxious first-year student sought out social support from other students in the laboratory.

Like Faith, Kyle asked if the feedback could be displayed for longer to make it more readable. This was done in the next generation of pre-laboratory activities. Additionally, like Jake, he asked if hints could be made available more often if a student made repeated attempts without getting a question right. To help avoid creating a sense of frustration this was also increasingly brought in during the next generation of pre-laboratory activities.

Maya

Maya did not complete the pre-laboratory activity feedback survey, but she did complete the CLASEQ at the start of the semester. Like Kyle, Maya was in her first semester, a native English speaker and not a mature-age student. She had previously studied chemistry at an upper-secondary level but not at a tertiary level. She had rated this prior experience as a 3 out on 10 on a scale of aversiveness and expected the unit CHEM1002 to be the same, she expected the laboratory sessions to be slightly more aversive (4 out of 10). Maya wanted a high distinction but only expected a distinction. She reported slightly below average anxiety and below average self-efficacy.
Maya said that what she liked least about the laboratory sessions was that they were stressful because of the assessment, and that even if she prepared well, she felt she would forget under pressure. Whereas other students, like Kyle, mentioned the other students in the laboratory as a source of support Maya said she worried that they knew more that her. It may be interesting in another study to examine in more detail the relationships between social perceptions, social interactions, anxiety and self-efficacy in the laboratory.

“I feel like before I also was worried that more other people would know more about it than me, so I didn’t want to do badly if everyone else wasn’t doing badly as well. I think it’s- there’s nothing particularly that you’re stressed about in the lab you’re just- when you’re there you’re- everything’s going on at the same time ‘cause you’re rushing around and it’s hard to focus and remember what you’re supposed to do.”

Like several comments made by other students, this comment brings to mind cognitive load theory. One way of interpreting Maya’s comment is that a high cognitive load causes her, and possibly other students, to feel stressed in the laboratory and to hinder their ability to do the work.

Maya said she was confident about the techniques that she had previously done. In other words, the techniques which she had accumulated mastery experiences with. Maya also brought up productive and unproductive worrying.

“I think, before I go in, I’m probably more stressed… I’m just constantly thinking about everything that could go wrong, and then when I get in there- because I actually have the stuff and I can actually do it… I know that I can do it and it’s not as stressful because you’re not just over-thinking it.”
The worrying Maya described engaging in before the laboratory, thinking about what could go wrong rather than how to make it go well, is unproductive. In the laboratory though she was able to channel that worry into a productive doing of what needed to be done.

Unlike Kyle, who said that following the procedure was the most important thing to him, Maya said that for her it was important to understand what she was doing and why rather than blindly following the procedure. This may reflect that Maya values meaningful learning more than Kyle. It is unfortunate that she didn’t do the pre-laboratory evaluation survey as it would have been helpful to compare the two. However, although she did not want to do the laboratory work without understanding it Maya did also say that she thought it was important to follow the procedure and do the work properly. She also said that safety was important to her. However, when asked about her goals for each laboratory session, Maya said:

“To try and end up with the best result that I can, so with my product, the best thing, and then to try and answer- to get as many marks from the questions.”

Maya said that she thought how specific the interactive activities were to the laboratory sessions made them more helpful than the videos.

“I didn’t find the video was that helpful, it was very generic, there wasn’t anything specific. Whereas, the interactive activity is very specific to the lab. It explains specific things that I wouldn’t have been able to work out... It gets you thinking but then it does prepare you to make sure you do know the answer and... why you’re doing things.”
5.5 Summary

As seen with the first generation of pre-laboratory activities, pre-laboratory activities can be developed based on both previous research and student feedback. These activities can be evaluated as an intervention to reduce students’ anxiety and increase their self-efficacy by a combined use of surveys and interviews.

From the survey data it was found that the majority of students (81.5%) think that the pre-laboratory activities at least somewhat help reduce their anxiety about the laboratory sessions. It was also seen that the majority of student (80-90%) thought doing the pre-laboratory activities made them more confident about their ability to answer questions, manage time, and do the practical work, in the laboratory.

It was thought that understanding more about what aspects of laboratory work students thought were important would be helpful in developing the third generation of pre-laboratory activities. Given the control value theoretical framework, it was predicted that whether students were anxious about an aspect of laboratory work would depend not just on their self-efficacy but also on whether they value being able to do it well.

The results about what students think is important, especially the survey results, did not entirely align with existing literature. This may be partially due to methodology, bias or the difference between something that is important and something that is a goal. It was seen that when students were asked to rank different items in terms of their importance the order was: safety, understanding what was happening, getting a good grade, putting theory into practice, acquiring laboratory skills, following the procedure, getting the correct product and, of least perceived importance, getting a high yield. However, each of the four items rated as least important were mentioned as most important by at least one student during an interview. This emphasises the non-generalisable nature of interview results.
Furthermore, while students’ responses in the interviews and the surveys were generally consistent, there were some exceptions, especially when it came to what students thought was important. Grades were something which students tended to rank or state as less important but then use to explain their behaviour during interviews. However, some students were open about the fact that grades mattered to them.

There were generally fewer comments about fixing technical difficulties than were reported in the evaluation of the first generation of pre-laboratory activities. This is indicative that attempts to fix or eliminate the technical flaws were at least partially successful. Generally, the few technical comments were only focused on the display times and depth of the feedback given to students when answering question in the pre-laboratory activity. Other than that, students mainly asked for a more in-depth explanation of the theory and for the inclusion of specific information. For example, one student asked for content that taught the names of different pieces of glassware. These reflections were used in the development of the third generation of pre-laboratory activities.
6.0 DEVELOPMENT OF AND FEEDBACK ON THE THIRD GENERATION OF PRE-LABORATORY ACTIVITIES

6.1 Introduction

This chapter discusses the development of the third generation of interactive pre-laboratory activities, as well as the student feedback collected via surveys and interviews. In the feedback surveys given during the implementation of the third generation of the activities, questions were included about: students’ perceptions of the impact of CLA and CLSE on their laboratory work, their reasons for completing the activities, and the impact of the improved activities on their perceptions of the difficulty of the laboratory sessions.

6.2 Changes from the Second to the Third Generation of Pre-Laboratory Activities

The aim for the third generation of the pre-laboratory activities was to incorporate the feedback students gave about the content of the second generation. The feedback given on the second generation of pre-laboratory activities was less about technical issues and more about content. While there were certain technical issues to address, for example extending the display time of the feedback after a student answered a question, the main focus was on incorporating feedback on the content. For example, asking for more information on the equipment, the theory and the reasons behind why specific techniques are used.

One of the main changes from the second to third generation of the pre-laboratory activities was the change in design. Multiple students commented that they wanted newer software to be used. While Adobe Captivate 9 is the most recent release an attempt was made to make the content seem more modern by changing the style. Changing the style was simple as the slides had been designed in Microsoft PowerPoint and then uploaded to Captivate 9. Thus, changing the slides could be done with a few clicks in PowerPoint and the new slides uploaded to Captivate 9. This is seen in figures 6.1 and 6.2 below:
Figure 6.1: Design of the second generation of the of pre-laboratory activities.

Figure 6.2: Design of the third generation of the of pre-laboratory activities.
Another change made was the introduction of a “table of contents” slide instead of navigation buttons on the slides themselves, given that Captivate’s inbuilt navigation bar had made these obsolete. Students could click the title of any section to jump to the relevant slides (Fig 6.3).

![Figure 6.3: Table of contents slide.](image)

Finally, Mayer’s e-learning principles (Figure 1.5) were used to refine the content (Mayer, 2017). The principles of coherence, signalling, contiguity, segmenting, modality, personalisation and voice were already being incorporated, the technology did not allow for the incorporation of the embodiment principle and the pre-laboratories themselves were already a form of pre-training. However, in this last iteration a focus was placed on implementing the redundancy principle. That is, where possible, the audio was not just someone reading out what was written on the slide. Instead there was a separate script containing a full explanation of the slides, and the slides themselves only contained instructions and key phrases. It should be noted though that while this may aide the learning of the majority of the students, future generations of these activities should consider the needs of students who have visual or auditory impairments.
Three surveys probing CLA and CLSE were given in semester two of 2018. The results from these surveys that relate to anxiety and self-efficacy are discussed in chapter seven. However, they were also used in building the case studies presented in this chapter.

Additionally, the final survey, distributed to students ($N = 55, 78.6\%$) at the end of semester two in 2018, included pre-laboratory activity evaluation questions that are discussed here. This survey asked whether students agreed with statements about their mistakes or not, self-efficacy and anxiety in the laboratory. It is included in Appendix L. Students were asked about their anxiety relating to making mistakes as the experienced demonstrator interviewed in the previous semester believed that making mistakes was something students were highly anxious about. Additionally, mistakes often take time to correct and therefore may be a source of anxiety given students reported high levels of anxiety about finishing on time. The results are summarised in table 6.1. It can be seen that generally students somewhat agreed that doing the interactive pre-laboratory activities reduced their CLA and improved their CLSE.

![Predicting Solubility](image.png)

*Figure 6.4: Demonstration of the limited text used to incorporate the redundancy principle.*
Table 6.1 Students’ average agreement with various statements about their anxiety, self-efficacy, mistakes and preparation on a Likert scale of 1-5 (N = 55)

<table>
<thead>
<tr>
<th>Statement</th>
<th>Med. (1-5)</th>
<th>Mean (1-5)</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>I was able to fix any mistakes I made during the labs</td>
<td>4</td>
<td>3.75</td>
<td>0.80</td>
</tr>
<tr>
<td>I made a lot of mistakes during the labs</td>
<td>3</td>
<td>2.91</td>
<td>1.01</td>
</tr>
<tr>
<td>I was able to take in and process new information during the labs</td>
<td>4</td>
<td>3.73</td>
<td>0.73</td>
</tr>
<tr>
<td>Preparing for the lab made me less anxious about the lab</td>
<td>5</td>
<td>4.20</td>
<td>1.03</td>
</tr>
<tr>
<td>Doing the interactive pre-lab made me less anxious about the lab</td>
<td>4</td>
<td>4.07</td>
<td>1.07</td>
</tr>
<tr>
<td>Doing the online quizzes made me less anxious about the lab</td>
<td>3</td>
<td>3.09</td>
<td>1.39</td>
</tr>
<tr>
<td>Doing the pre-lab activities made me more confident about the lab</td>
<td>4</td>
<td>3.87</td>
<td>1.19</td>
</tr>
</tbody>
</table>

From a Wilcoxon Signed Rank test, students agreed significantly more that the interactive pre-laboratory activities made them less anxious about the laboratories than the online quizzes (Z = -4.688, p > 0.001).

Students’ Perceptions of Their Mistakes, Anxiety and Confidence

Figures 6.5, 6.6 and 6.7 show students’ responses to questions about their mistakes, anxiety and confidence during laboratory sessions. The most common responses were that mistakes were a valuable learning opportunity, and that both anxiety and confidence neither help nor hinder laboratory work.

Figure 6.5 How students see the mistakes they make during laboratory sessions

(N = 55)
Figure 6.6 How students see their anxiety during laboratory sessions (N = 55)

Figure 6.7 How students think about being confident in laboratory sessions (N = 55)

Students’ Reasons for Completing the Pre-Laboratory Quizzes and Interactive Activities

98% of students reported doing all the online quizzes, in contrast only 79.2% of student on average did the interactive pre-laboratory activity. Figures 6.8 and 6.9 show students’ reasons for completing the interactive pre-laboratory activities and the pre-laboratory quizzes. The clear majority of students who completed the interactive pre-laboratory activity did so to prepare for the laboratory. Another way of viewing this is that the majority of students indicated intrinsic motivations for completing the interactive pre-laboratory activities. This is important as intrinsic motivation is correlated with higher achievement and self-efficacy (Ross, Perkins and Bodey, 2016), than doing a task because it is expected or assessed, which reflects a more extrinsic motivation.
Students’ Perceptions of the Pre-Laboratory Activities: Perceived Difficulty

To further investigate the impact that the pre-laboratory activities had on students’ laboratory experience, students were asked how difficult they expected the laboratory sessions to be before and after the pre-laboratory activity, how difficult the laboratory sessions actually were, and how difficult they thought the laboratory sessions would have been without the pre-laboratory activity. It is seen that students generally thought the laboratory session would be less difficult after completing the pre-laboratory activity. This decrease was found to be significant using a Wilcoxon Signed Rank test ($p < 0.001$). There was no significant difference between students’ revised expectations and how difficult they thought the laboratory sessions actually were ($p = 0.251$).
Lastly it is seen that students thought that the laboratory sessions would have been more difficult without the interactive pre-laboratory activities, again this was found to be significant \( p < 0.001 \). This suggests that the pre-laboratory activities helped students develop realistic expectations of how difficult the laboratory sessions would be (Figure 6.10).

![Graph showing impact of pre-laboratory activities on students' expectations of difficulty](image_url)

*Figure 6.10 Impact of pre-laboratory activities on students’ expectations of difficulty (n = 55)*

### 6.4 Evaluation of the Third Generation of Pre-Laboratory Activities: Case Studies

Four interviews were conducted with students after their end of semester exams. The prompts for the interviews are included in Appendix M. The interviews aimed to provide support for the usefulness of the data collected in the surveys. They also aimed to investigate in more detail the laboratory-related worry, preparation and goals of the students interviewed. Specific feedback the students had for improving the pre-laboratory activities was also discussed with the students in more detail.
Noah

Noah was an international student from America who spoke English as his first language. This was his first semester at the University of Western Australia, but he had prior experience of studying chemistry at a tertiary level. He both wanted and expected to receive a high distinction at the start of the year. His prediction of how much he would enjoy the unit (6/10) and how much he would enjoy the laboratory sessions (7/10), remained the same before and after completing the pre-laboratory activities. Noah’s CLA decreased and his CLSE increased after doing the pre-laboratory activity. However, at the start and end of the semester he had higher than average anxiety and lower than average self-efficacy.

Noah said that he liked the hands-on nature of the laboratory sessions as he felt that it helped him understand better. However, he said that he didn’t like one session in particular, the molecular-models laboratory. This was because he thought that the approach his home university took, of getting students to purchase a model kit and use it in class and at home, was more helpful. Speaking about the laboratory sessions in general he said:

“I didn't dislike any part of it because it kind of seemed, at some level, what I was expecting.”

It is known that whether students’ expectations are met affects how they feel about the laboratory (Galloway & Bretz, 2015; Galloway et al., 2015). The use of pre-laboratory activities to communicate expectations to students has been recommended (Reid and Shah, 2007). Additionally, it was seen in this study that the pre-laboratory activities corrected students’ expectations of how difficult the laboratory sessions would be. The effect of the pre-laboratory activities on students’ expectations may affect CLA and CLSE but this had not yet been confirmed.
Noah reported that before the laboratory he was most worried about preparation. This may reflect productive worrying, given that he related worrying to preparation.

“How am I going to be prepared for this was what I was most worried about and how am I going to deal with the questions when they come up.”

This was consistent with both his survey results, in which he said he was most anxious about answering the assessed questions and completing the work in time. It was also consistent with what he said in the interview when asked what the biggest source of stress was for him in the laboratory.

“I mean probably answering the questions correctly for a grade, for- I tend to be a bit of a perfectionist, so if my product isn't perfect, I overthink that sometimes.”

Grades also came up when Noah was asked about what made a laboratory session successful in his opinion:

*Question: How would define a lab that’s successful?*

*Noah: “So there's obviously the grade component. I'm not going to lie about that.”*

However, the grade he received was not the only way Noah measured if a laboratory session had been successful. He added that it was also important that he learned what he was doing and why, reasoning that he was an engineering student and that being able to translate principles from the small-scale of a teaching laboratory to the big-scale of an engineering firm was an important skill. In terms of necessary skills for successfully completing a laboratory session Noah was sure that time-management was the core skill for him.
Noah said that he thought making use of the pre-laboratory resources offered was important, whether that was pre-laboratory lectures in the US or the interactive activities here. He was then asked what resources he thought would be help him get a good grade and develop transferrable knowledge. He replied that he thought the current pre-laboratory activities were conducive to doing helping him with that. Also, in his survey responses he strongly agreed that doing the interactive pre-laboratory activities reduced his CLA and improved his CLSE.

Later on, talking about how the pre-laboratory activities could be improved to help him understand the theory, he said that he had personally not found the practice yield calculations helpful as he already had high self-efficacy about doing them. This was reflected in that although he had a high (4 out of 5) score for anxiety about answering assessed questions he also had high (4 out of 5) self-efficacy about answering them. Talking about how the pre-laboratory activities could better prepare him to succeed at the practical aspects of the laboratory he mentioned including videos because of the usefulness of being able to see in advance what he was going to have to do. This aligns with the theory that seeing a task modelled increases self-efficacy (Feltz, Landers and Raedar, 1979).

Lastly, Noah also brought up the importance of the guided-response phase of the psychomotor taxonomy (Simpson, 1971). Consistent with other research that has found students need the practical experience in the laboratory to learn practical skills (Ramos et al. 2016; Potkonjak et al. 2016), he explained that:

“...being able to think about what each piece did rather than just doing each piece helped with [learning to predict what technique would be used], and then having the opportunity to go later and actually do it. It's kind of twofold.”
Vanessa

Vanessa was not in her first semester at the University of Western Australia and had previously studied a chemistry unit at a tertiary level. She was a native English speaker who indicated that she wanted a distinction and expected a high distinction. She did not complete the survey given before completing the first pre-laboratory activity but did complete the survey given after it. At that point she predicted that she would find the unit and the laboratory sessions to be very enjoyable, giving both a score of 8/10. After completing the first interactive pre-laboratory activity both her anxiety and self-efficacy were higher than average. At the end of the semester, she reported a higher than average level of both anxiety and self-efficacy.

When asked what she liked most about the laboratory sessions Vanessa said:

“To be honest, probably the pre-lab stuff that you did. Mainly because the only other labs I've ever done was the previous semester, and that was in the intro chem unit... and I liked the lab stuff there because you did stuff with a partner so you could actually work through things together... I missed that part a lot in this semester's labs but doing the pre-lab stuff made it a bit- a lot easier, coming into the labs knowing that I was going to work by myself- to know what I was doing, so then I didn't feel like the questions I was asking were really that stupid because I'd done the work before.”

Vanessa’s response reflected the kind of impact that the pre-laboratory activities aimed to have on students. Her answer implies that she had higher self-efficacy having done the pre-laboratory activity, both in her understanding and in her ability to engage by asking questions. Vanessa said that she liked making products that were familiar, like aspirin, as to do so gave her a sense of achievement.
Vanessa said that she didn’t like working alone in the laboratory sessions, but that she understood that it made individually marking students easier. She reported being most stressed about finishing on time and balancing working quickly with doing the work well and getting a good result. Interestingly, she rated making mistakes and interpreting data as causing more anxiety (4 out of 5) on her end of semester survey than time management (3 out of 5). She also rated her self-efficacy about completing the work in time as higher (5 out of 5) than fixing or avoiding mistakes (3 out of 5) and interpreting data (4 out of 5). This may reflect a change in her feelings over time or the fluid nature of feelings.

Vanessa agreed that she was less anxious about doing a task in the laboratory if she was confident about her ability to do it well. When asked to expand, she said:

“I think overall [I am less anxious when I’m confident], but then at the same time, I think- especially with these... your pre-lab stuff, doing things for the first time was- I felt a lot less anxious doing something for the first time after seeing... the lab prep stuff, than I was doing stuff without that."

Vanessa was asked if that was because the pre-laboratory activities made her more confident or something else, to which she replied:

“I think a couple of things. I think it made me a bit more confident. It was also interactive, so then I knew that I was actually understanding it not just watching a video and then hoping that it [had] kind of sunk in... If there was just a video I might feel like: but I don't actually understand this bit or like: what if I get the calculation wrong, or something. That was all taken care of for me."

It seems that what Vanessa was describing was not just a vague increase in her confidence that the laboratory would go well, but rather, an increase in her self-efficacy regarding understanding the theory behind the laboratory.
Vanessa also went on to describe how the pre-laboratory activity had helped her answer one of the questions asked in the laboratory. This was the kind of mastery experience it was hoped that the pre-laboratory activities would help students to attain.

When discussing what a successful laboratory would look like for her, Vanessa said:

“*My last lab I would say was probably one of my most successful, mainly because I was very happy with the yield of the product I got. And I finally understood what we were doing because I was now up to date with the lectures and everything.*”

Vanessa was then asked whether she thought a laboratory session in which she got a good yield and understood the theory but got a bad grade would still be successful in her opinion. She responded that she would feel her time in the laboratory was successful even if the outcome, the grade, was unsuccessful. She also said that her goal for the laboratory sessions was to develop laboratory skills.

Vanessa said that, in her opinion, the type of preparation necessary for a laboratory to be successful, was doing the pre-laboratory work given, in order to understand the theory. Talking about what skills were necessary, she mentioned time-management, the ability to prioritise tasks and the ability to set appropriate goals, in addition to preparation.

Vanessa said that she thought that the pre-laboratory activities sufficiently covered the theory for the laboratory. She also said that being more direct wouldn’t have been helpful because it would be erring on spoon-feeding. Again, with respect to how the pre-laboratory activities could be improved to prepare students to do the practical work, Vanessa said that she thought that she wouldn’t change anything as she always felt prepared having done the interactive pre-laboratory activities. This aligned with her survey responses including her strong agreement that doing the interactive pre-laboratory activities improved her CLSE and reduced her CLA.
Samantha was not in her first semester at the University of Western Australia, but this was her first tertiary level chemistry unit. She was a native English speaker who indicated that she wanted and expected a distinction. She did not complete the survey after the first pre-laboratory activity, but before doing the first pre-laboratory activity she reported a higher than average level of anxiety, and a lower than average level of self-efficacy. After the semester she reported a lower than average level of anxiety and a higher than average level of self-efficacy.

Samantha’s favourite thing about the laboratory sessions was seeing the chemistry in a hands-on way. Her least favourite thing was the time pressure of trying to do the practical work and answer the questions on the worksheet. What questions would be on the worksheet was also what she said she worried most about before going into a laboratory session. She clarified:

“What questions are going to be asked, but going in doing the experiment, because we do that in the pre-labs and all that stuff, I think, you know what you’re doing. It’s not like you’re going in and you have no idea… But yeah, it’s just- what questions are going to be asked, can you answer the questions, how hard it's going to be, what the questions are going to be, etc.”

The worksheet was also the biggest source of stress in the laboratory for Samantha. It is hard to say whether this was consistent with her survey response, as she rated her anxiety about all aspects of laboratory work as 2 out of 5 and her self-efficacy about all aspects of laboratory work as 3 out of 5. She reported that having other students around her who were in the same situation as her, along with helpful demonstrators, helped her to feel ok in the laboratory.
Samantha said that what she looked forward to most in the laboratory was connecting the theory to the practical work. She went on to quantify that it didn’t really excite her but that she saw it as an additional learning opportunity on top of the lectures.

Sarah said she felt confident she could complete the laboratory sessions. Following which, she was asked:

*Question: Do you reckon that makes you less anxious about doing them?*

*Samantha:* Yeah, I definitely. I feel like [if] you feel are you confident or competent to do that kind of thing, [it] boosts your confidence in doing what you need to do. Especially if you if you know what you're doing, because if you don't know what you're doing and just being familiar, I guess, just really helps.

This was an interesting response in several ways. Firstly, Samantha connected familiarity with not being anxious, as did Vanessa, which does not align with Dalgarno, Bishop, Adlong and Bedgood’s (2009) findings that familiarity was not an important factor in determining anxiety. Secondly, her description aligns with the control-value theory of anxiety that students will be anxious when they see something as important (what you need to do) and lack self-efficacy (Pekrun, Goetz, Titz, & Perry, 2002). It is also interesting that she linked understanding the task, which could be seen as a type of being prepared, with self-efficacy about doing what needed to be done.

Samantha said that the skills she learned in the laboratory sessions were the practical, technique-based ones, such as recrystallisation. She said that she developed these skills through preparation, reading the laboratory manual, watching the videos and doing the interactive activities.

“*Because then you knew what you were doing away from the lab and once you get to the lab you just know you just have to physically do it.*”
This reflects a process of first seeing skills modelled and then being able to use the knowledge acquired from the modelling stage in order to gain mastery experiences. The influence of mastery experiences on anxiety can also be seen in her description about how her anxiety about time-management changed over the semester:

“I think once you finish the first and second lab, you get less anxious with the time management, which then probably transfers into your work and your accuracy.”

Interestingly this statement reflects the view that anxiety impairs performance whereas in her survey Samantha said that she didn’t think anxiety helped or hindered her performance in the laboratory. She did, however, indicate that she though lacking self-efficacy reduced her ability to do well. In her interview she said that making a mistake and having to redo something damaged her self-efficacy but that time management and seeing other students do the steps made helped her rebuild her self-efficacy again.

“seeing other people doing [the steps] as well [helps me to be confident] ... them doing it correctly you're like, 'well obviously I can do it correctly... [they’re] the same... like me.”

This statement supports findings that seeing a skill modelled by someone who is a peer is more effective for building self-efficacy than seeing it modelled by an expert (Feltz et al., 1979).

In Samantha’s opinion a successful laboratory session involved:

“Finishing under the time... feeling confident that I've answered the worksheet correctly... doing the experiment correctly... learning something from it. You could make a mistake from it, that doesn't mean you aren't successful, but hopefully you learned something from it, and then the next lab you can just go up from there.”
This was consistent with her survey response, in which, she said that she saw her mistakes as a valuable learning opportunity. She said that to prepare well and be able to do those things, it was helpful to do the pre-laboratory work, including reading the laboratory manual, doing the pre-laboratory activities and the quizzes, going through lecture notes and developing a background understanding. However, she also added that she thought that in order to learn the practical skills it was necessary to actually practice them. She thought it was helpful for students to not expect to be able to do the laboratory work perfectly straight away, but to trust that improvement would come with practice.

Samantha said that she thought it would be better if the pre-laboratory activities didn’t necessarily assume everyone was up to date with the lecture content. While it’s true that not all students will not be up to date with the lecture content that does not make it unreasonable to assume that they ought to be. It should also be noted that these pre-laboratory activities were created separately from the lectures and therefore did not intend to assume the lecture content as prior knowledge. Unlike some of the other students Samantha liked the way in which the pre-laboratory activities explained yield calculations and gave students opportunities to practice them. She did agree with the other students interviewed who said that more video footage of the techniques would have been helpful. She also mentioned that the way in which the interactive pre-laboratory activity content was linked to what would be asked on the worksheet helped her prepare.
William

William, like Samantha, was not in his first semester at the University of Western Australia but was studying a chemistry unit at a tertiary level for the first time. He was a native English speaker who indicated that he wanted a high distinction but expected a distinction. Also, like Samantha, he completed the survey before doing the first interactive pre-laboratory activity but not after. Unlike most students he reported a higher average anxiety, and lower average self-efficacy at the end of the semester. However, in general he reported lower than average levels of anxiety and higher than average levels of self-efficacy.

During the interview it emerged that William was not majoring in chemistry, rather, he was taking CHEM1002 as a broadening unit because of an inspiring chemistry teacher in year 12. William said that he most liked the pretty colours of the chemicals and making a product, and that he least liked working alone and the fact that the laboratories were assessed. He reported being most worried about making mistakes. However, while on his survey he said he saw them as a valuable opportunity to learn, in the interview he said:

“I mean it's basically [that] you don't want to stuff it up too much [so] that you have to redo things, [or] lose marks. Because it all comes down to the marks at the end of the day. It's not exactly just a fun experience.”

William said that he generally felt “pretty good” in the laboratory. However, he did liken it to being in an aeroplane and expressed a sense of relief to be out in the fresh air afterwards. He said that for himself the biggest source of stress in the lab was asking the demonstrators questions. He said this was because he felt bad if he asked too many questions and was worried about asking and then not understanding the answer. This was interesting as most students responding to the CLASEQ had reported low levels of anxiety and high levels of self-efficacy about asking for help from a demonstrator.
In fact, William himself reported low anxiety (2 out of 5) and high self-efficacy (4 out of 5), for asking for help from a demonstrator. He reported higher levels of anxiety and lower levels of self-efficacy about making mistakes, interpreting data and answering assessed questions, than about asking a demonstrator for help. This was in line with his statement that he was most worried about making mistakes but not with his statement that asking questions was his biggest source of stress. This serves to highlight the difficulty of studying the affective domain. It is entirely possible that his feelings had changed, or that he was just responding with the first thing that came into his head during the interview.

In his survey William had said that he didn’t think anxiety helped his performance but that it didn’t impair it either. He did, however, think that high self-efficacy helped him do well. He strongly agreed that preparing for the laboratory made him less anxious about the practical session, that doing the interactive activities specifically made him less anxious about the practical session, and that doing the interactive pre-laboratory activities improved his CLSE. In the interview he reaffirmed this:

“you might have prepared well and then have more confidence, be more confident.”

However, when asked in the interview what most helped develop his confidence he said:

“Probably just being chucked into it, having to do it.”

This reflects what student said in their surveys. That they thought that preparing well increased their self-efficacy. This supports our hypothesis that pre-laboratory activities can have a direct effect on self-efficacy because students feel more prepared.
William also brought up another good point, that even if preparing for the laboratory builds self-efficacy, this self-efficacy will be tested by the laboratory. If a student has self-efficacy, but lacks skill, experience will not be one of mastery and thus their self-efficacy will be diminished. This highlights the need for the pre-laboratory activities to focus on preparing students to succeed as a way to build sustainable self-efficacy. William put it this way:

*Question: Do you think that when you're confident about your ability to do the labs well that makes you less anxious about doing them?*

*William: “A little bit... I mean confidence- I'm always fairly confident going into that, but whether that's true confidence depends on the lab itself. Some labs I think will be ok and then it's actually a bit different. Other labs I'm like: it's going to be really hard and it's actually really easy.”*

While his response didn’t really elaborate on his perception of the relationship between anxiety and self-efficacy it did seem that he thought if a laboratory session was more difficult than expected it would reduce self-efficacy. This seems consistent with Rodgers, Conner, and Murray (2008) who found a strong correlation between perceived difficulty and self-efficacy. It is also in line with Bandura’s (1997) hypothesis that people lacking self-efficacy will rate tasks as more difficult compared to people with higher self-efficacy.

Finally, William was asked about what made a laboratory session successful in his opinion, what would be necessary to achieve that, and how the pre-laboratory activities could be improved to help him achieve that. His response bore similarities to the response Vanessa gave. He said that a successful laboratory session was one in which he…
“...understood the questions that they asked, like, got the gist of where it's going. Because each one has a theme and if you understood the theme then you sort of understood it, basically, and if you got the final product in the end, which you get every time basically, but I think like, if it's like a decent yield. Then it's kind of like: yeah I did pretty good.”

The things he thought were necessary to achieve this were:

“Time management, responsibility, I don't know, like, a bit of "drive forward, keep going, keep on, positive energy, don't give up." Yeah. What else? They're the main ones I think, just prior knowledge... [Being] able to study for it a little bit.”

It was interesting that he mentioned perseverance and motivation, which are affective-domain constructs. It should also be noted that motivation was one thing Agustian and Seery (2017) mentioned as a possible application of pre-laboratory activities. William’s mention of prior knowledge and studying linked back to his earlier comments on the importance of preparation. He said that the pre-laboratory activities could be changed to be more helpful as a preparatory resource by giving a more detailed overview of the theory. He gave the example of going through a mechanism step by step, when reminded that the pre-laboratory activities had gone through mechanisms stepwise and shown an example in the most recent pre-laboratory activity, he clarified that he would have liked a more in depth explanation of why it happens the way it does as that would be the type of question asked in the exam.
6.5 Summary

In the three semesters, during which the pre-laboratory activities were developed, it was seen that interactive pre-laboratory activities that model skills, give opportunity to practice cognitive skills and prepare students to gain mastery can be developed using Adobe Captivate 9. These were improved by collecting students’ feedback and investigating what they saw as important. It was found that it was important to make students aware of the resources available to them, resolve technical issues, and implement literature principles on good e-learning resources. These activities could be evaluated through the use of surveys and interviews.

In general students agreed that doing the pre-laboratory activities reduced their CLA, increased their CLSE and that the interactive activities were more effective at doing that than the online quizzes. It was also seen that students thought the laboratories would be less difficult after doing the pre-laboratory activities. They also thought the laboratory sessions would have been more difficult without the pre-laboratory activities.

Whereas nearly 100% of students did the online quizzes, only 80% of students on average completed the interactive pre-laboratory activities. More students may do the pre-laboratory activities if they were assessed but even without an attached grade they were fairly well used by students. When asked why they did the quizzes the reasons given by the vast majority of students included the fact they were assessed. In contrast the majority of students said they did the pre-laboratory activities purely to prepare.

Despite having already been through several rounds of improvement the students still had suggestions for how the pre-laboratory activities could be improved in the future. The most common were to include more videos of the practical work and give a more detailed explanation of the theory.
7.0 STUDENTS’ CLA AND CLSE DURING AN INTERVENTION

7.1 Introduction

In this chapter there will be an analysis and discussion of the data collected using the CLASEQ during the three semesters in which the students had access to the interactive pre-laboratory activities. The focus of this chapter is the usefulness of the CLASEQ to evaluate the impact of the interactive pre-laboratory activities on anxiety and self-efficacy. The results obtained using the CLASEQ in semester two 2017, and semesters one and two 2018, are presented and discussed.

7.2 Results from Semester Two 2017

Comparison with Semester One 2017: Aspects of Chemistry Laboratory Work & Anxiety

Table 7.1 shows that for some factors there was a significant reduction in anxiety between the beginning of semester one and the beginning of semester two. Values of \( p \), \( Z \) and \( r \), calculated from the results of a Mann Whitney U test, are given. It should be noted that the presence of significant differences meant that a comparison of semester one without the pre-laboratory and semester two with the pre-laboratory was not a valid way to evaluate the impact of the pre-laboratory activity. Changes to the research method were adopted in 2018 to account for this.

<table>
<thead>
<tr>
<th>Aspect of Laboratory Work</th>
<th>Significance (( p ))</th>
<th>Size (( Z ))</th>
<th>Size (( r ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with Other Students</td>
<td>0.539</td>
<td>-0.614</td>
<td>0.060</td>
</tr>
<tr>
<td>Asking a Demonstrator for Help</td>
<td>0.186</td>
<td>-1.321</td>
<td>0.130</td>
</tr>
<tr>
<td>Working with Chemicals</td>
<td>0.014</td>
<td>-2.461</td>
<td>0.241</td>
</tr>
<tr>
<td>Working with Chemical Equipment</td>
<td>0.044</td>
<td>-2.018</td>
<td>0.198</td>
</tr>
<tr>
<td>Recording Data</td>
<td>0.003</td>
<td>-2.964</td>
<td>0.291</td>
</tr>
<tr>
<td>Interpreting Data</td>
<td>0.011</td>
<td>-2.540</td>
<td>0.249</td>
</tr>
<tr>
<td>Answering Assessed Questions</td>
<td>0.022</td>
<td>-2.287</td>
<td>0.224</td>
</tr>
<tr>
<td>Completing the Work in Time</td>
<td>0.001</td>
<td>-3.231</td>
<td>0.317</td>
</tr>
</tbody>
</table>
Table 7.2 presents the results of a Mann Whitney U test performed to identify significant differences in anxiety between the end of semester one and the end of semester two. However, no significant differences were observable.

Table 7.2: Comparison of CHEM1002 students’ anxiety at the end of semesters one \((N = 54)\) and two \((N = 21)\) in 2017

<table>
<thead>
<tr>
<th>Aspect of Laboratory Work</th>
<th>Significance ((p))</th>
<th>Size ((Z))</th>
<th>Size ((r))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with Other Students</td>
<td>0.728</td>
<td>-0.348</td>
<td>-0.05</td>
</tr>
<tr>
<td>Asking a Demonstrator for Help</td>
<td>0.753</td>
<td>-0.315</td>
<td>-0.05</td>
</tr>
<tr>
<td>Working with Chemicals</td>
<td>0.407</td>
<td>-0.829</td>
<td>-0.12</td>
</tr>
<tr>
<td>Working with Chemical Equipment</td>
<td>0.837</td>
<td>-0.206</td>
<td>-0.03</td>
</tr>
<tr>
<td>Recording Data</td>
<td>0.092</td>
<td>-1.687</td>
<td>-0.25</td>
</tr>
<tr>
<td>Interpreting Data</td>
<td>0.754</td>
<td>-0.313</td>
<td>-0.04</td>
</tr>
<tr>
<td>Answering Assessed Questions</td>
<td>0.551</td>
<td>-0.596</td>
<td>-0.09</td>
</tr>
<tr>
<td>Completing the Work in Time</td>
<td>0.958</td>
<td>-0.053</td>
<td>-0.01</td>
</tr>
</tbody>
</table>

Comparison with Semester One 2017: Aspects of Chemistry Laboratory Work & Self-Efficacy

Another Mann Whitney U test was performed to test for significant differences in self-efficacy at the start of semesters one and two in 2017. Table 7.3 shows that students only had higher self-efficacy about completing the work in time and that the effect size of this was small.

Table 7.3: Comparison of CHEM1002 students’ self-efficacy at the start of semesters one \((N = 80)\) and two \((N = 24)\) in 2017

<table>
<thead>
<tr>
<th>Aspect of Laboratory Work</th>
<th>Significance ((p))</th>
<th>Size ((Z))</th>
<th>Size ((r))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with Other Students</td>
<td>0.932</td>
<td>-0.085</td>
<td>0.01</td>
</tr>
<tr>
<td>Asking a Demonstrator for Help</td>
<td>0.537</td>
<td>-0.618</td>
<td>0.06</td>
</tr>
<tr>
<td>Working with Chemicals</td>
<td>0.750</td>
<td>-0.318</td>
<td>0.03</td>
</tr>
<tr>
<td>Working with Chemical Equipment</td>
<td>0.483</td>
<td>-0.702</td>
<td>0.07</td>
</tr>
<tr>
<td>Recording Data</td>
<td>0.057</td>
<td>-1.906</td>
<td>0.19</td>
</tr>
<tr>
<td>Interpreting Data</td>
<td>0.097</td>
<td>-1.658</td>
<td>0.16</td>
</tr>
<tr>
<td>Answering Assessed Questions</td>
<td>0.056</td>
<td>-1.914</td>
<td>0.19</td>
</tr>
<tr>
<td>Completing the Work in Time</td>
<td>0.019*</td>
<td>-2.350</td>
<td>0.23</td>
</tr>
</tbody>
</table>

The Mann Whitney U test results in Table 7.4 show that as for anxiety there was no observable significant difference between students’ self-efficacy at the end of semester one and the end of semester two.
Table 7.4: Comparison of CHEM1002 students’ self-efficacy at the end of semesters one (N =54) and two (N = 21) in 2017

<table>
<thead>
<tr>
<th>Aspect of Laboratory Work</th>
<th>Significance (p)</th>
<th>Size (Z)</th>
<th>Size (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with Other Students</td>
<td>0.951</td>
<td>-0.061</td>
<td>-0.01</td>
</tr>
<tr>
<td>Asking a Demonstrator for Help</td>
<td>0.365</td>
<td>-0.907</td>
<td>-0.14</td>
</tr>
<tr>
<td>Working with Chemicals</td>
<td>0.591</td>
<td>-0.537</td>
<td>-0.08</td>
</tr>
<tr>
<td>Working with Chemical Equipment</td>
<td>0.471</td>
<td>-0.720</td>
<td>-0.11</td>
</tr>
<tr>
<td>Recording Data</td>
<td>0.115</td>
<td>-1.577</td>
<td>-0.24</td>
</tr>
<tr>
<td>Interpreting Data</td>
<td>0.148</td>
<td>-1.445</td>
<td>-0.22</td>
</tr>
<tr>
<td>Answering Assessed Questions</td>
<td>0.089</td>
<td>-1.700</td>
<td>-0.25</td>
</tr>
<tr>
<td>Completing the Work in Time</td>
<td>0.915</td>
<td>-0.106</td>
<td>-0.02</td>
</tr>
</tbody>
</table>

Demographic Changes Throughout 2017

The changes in the demographic information of the students who completed the CLASEQ at the start and end of both semesters in 2017 are summarised in Table 7.5.

Table 7.5: Demographic changes in survey responders throughout 2017

<table>
<thead>
<tr>
<th>Semester</th>
<th>Pre-Semester 1</th>
<th>Post-Semester 1</th>
<th>Pre-Semester 2</th>
<th>Post-Semester 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>80</td>
<td>54</td>
<td>24</td>
<td>21</td>
</tr>
<tr>
<td>Male (%)</td>
<td>45.0 %</td>
<td>40.7 %</td>
<td>41.7 %</td>
<td>45.5 %</td>
</tr>
<tr>
<td>Female (%)</td>
<td>55.0 %</td>
<td>59.3 %</td>
<td>58.3 %</td>
<td>54.5 %</td>
</tr>
<tr>
<td>Mature Age</td>
<td>6.3 %</td>
<td>7.4 %</td>
<td>20.8 %</td>
<td>9.1 %</td>
</tr>
<tr>
<td>ESL</td>
<td>13.9%</td>
<td>18.5 %</td>
<td>29.2 %</td>
<td>18.2 %</td>
</tr>
<tr>
<td>1st Year at UWA</td>
<td>88.8%</td>
<td>87.0 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Prior University Chemistry Unit</td>
<td>6.3%</td>
<td>7.4 %</td>
<td>25.0 %</td>
<td>45.5 %</td>
</tr>
<tr>
<td>Prior Aversiveness</td>
<td>Mean = 4.06</td>
<td>Mean = 3.54</td>
<td>Mean = 3.09</td>
<td>Mean = 3.80</td>
</tr>
<tr>
<td></td>
<td>σ = 2.60</td>
<td>σ = 2.27</td>
<td>σ = 2.57</td>
<td>σ = 2.26</td>
</tr>
<tr>
<td>Expected Aversiveness</td>
<td>Mean = 5.48</td>
<td>Mean = 4.71</td>
<td>Mean = 3.83</td>
<td>Mean = 4.00</td>
</tr>
<tr>
<td></td>
<td>σ = 2.33</td>
<td>σ = 2.20</td>
<td>σ = 2.96</td>
<td>σ = 2.28</td>
</tr>
<tr>
<td>Intent to do a Level 2 CHEM Unit</td>
<td>46.3%</td>
<td>33.3 %</td>
<td>58.3 %</td>
<td>63.6 %</td>
</tr>
</tbody>
</table>

The increase in students who had previously completed a chemistry unit, from 6.3 % at the start of semester one to 25.0 % at the start of semester two, is interesting. It seemed plausible that, due to mastery experiences, this may have contributed to the differences between the start of semester one and semester two.
However, comparing students who had previously done a chemistry unit at UWA at the start of either semester ($N = 18$) and those who had not ($N = 182$), the only significant difference was a reduction in anxiety about using chemical equipment ($p = 0.028$). Therefore, it is not expected that this is the cause of the observed differences. It is interesting though, that students with prior experience in the same laboratories were less anxious about using the equipment. Dalgarno, Bishop, Bedgood and Adlong (2009) suggested that familiarity did not greatly affect students’ anxiety. While, not conclusive, the results of this study indicate that when it comes to working with chemical equipment, familiarity may significantly affect anxiety.

It is also noteworthy that the data collected make it clear that the students who answered at the end of the semesters weren’t the same group that answered at the beginning of the semesters. Therefore, even when significant differences are visible, these differences are between the two groups of students, not necessarily between students in general at the start and end of a semester. Therefore, it was necessary, in the next round of collecting data, to collect student identifiers so that paired samples could be analysed. This was originally not done as it complicated the ethics application, but later proved necessary.

*Changes in Anxiety and Self-Efficacy from the Start to the End of Semester Two 2017*

Tables 7.6 and 7.7 show the changes in anxiety and self-efficacy that occurred in the CLA and CLSE reported by students at the beginning and the end of semester two 2017. Due to smaller sample sizes there are less significant results than were seen in semester one. In fact, no significant differences were apparent in students’ anxiety about any aspect of laboratory work. There were two aspects of self-efficacy which significantly increase over semester two. These were asking for help from a demonstrator and working with chemicals. Both of which had a medium effect size.
Table 7.6: Comparison of CHEM1002 students’ anxiety at the start (N = 24) and end (N = 21) of semester two in 2017

<table>
<thead>
<tr>
<th>Aspect of Laboratory Work</th>
<th>Significance (p)</th>
<th>Size (Z)</th>
<th>Size (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with Other Students</td>
<td>0.715</td>
<td>-0.366</td>
<td>-0.05</td>
</tr>
<tr>
<td>Asking a Demonstrator for Help</td>
<td>0.691</td>
<td>-0.397</td>
<td>-0.06</td>
</tr>
<tr>
<td>Working with Chemicals</td>
<td>0.236</td>
<td>-1.186</td>
<td>-0.18</td>
</tr>
<tr>
<td>Working with Chemical Equipment</td>
<td>0.305</td>
<td>-1.025</td>
<td>-0.15</td>
</tr>
<tr>
<td>Recording Data</td>
<td>0.146</td>
<td>-0.717</td>
<td>-0.11</td>
</tr>
<tr>
<td>Interpreting Data</td>
<td>0.548</td>
<td>-0.602</td>
<td>-0.09</td>
</tr>
<tr>
<td>Answering Assessed Questions</td>
<td>0.778</td>
<td>-0.281</td>
<td>-0.04</td>
</tr>
<tr>
<td>Completing the Work in Time</td>
<td>0.641</td>
<td>-0.466</td>
<td>-0.07</td>
</tr>
</tbody>
</table>

Table 7.7: Comparison of CHEM1002 students’ self-efficacy at the start (N = 24) and end (N = 21) of semester two in 2017

<table>
<thead>
<tr>
<th>Aspect of Laboratory Work</th>
<th>Significance (p)</th>
<th>Size (Z)</th>
<th>Size (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with Other Students</td>
<td>0.330</td>
<td>-0.974</td>
<td>-0.15</td>
</tr>
<tr>
<td>Asking a Demonstrator for Help</td>
<td>0.003</td>
<td>-2.943</td>
<td>-0.44</td>
</tr>
<tr>
<td>Working with Chemicals</td>
<td>0.030</td>
<td>-2.176</td>
<td>-0.32</td>
</tr>
<tr>
<td>Working with Chemical Equipment</td>
<td>0.052</td>
<td>-1.941</td>
<td>-0.29</td>
</tr>
<tr>
<td>Recording Data</td>
<td>0.146</td>
<td>-1.454</td>
<td>-0.22</td>
</tr>
<tr>
<td>Interpreting Data</td>
<td>0.503</td>
<td>-0.670</td>
<td>-0.10</td>
</tr>
<tr>
<td>Answering Assessed Questions</td>
<td>0.373</td>
<td>-0.891</td>
<td>-0.13</td>
</tr>
<tr>
<td>Completing the Work in Time</td>
<td>0.197</td>
<td>-1.291</td>
<td>-0.19</td>
</tr>
</tbody>
</table>

A lot was learned in semester two of 2017 about data collection. The need for larger sample sizes, the inability to pair data and the differences between the groups of students who responded to each survey limited the usefulness of the results. It was decided that if the CLASEQ was going to be used to evaluate the interactive pre-laboratory activities it needed to include a way to identify respondents. The easiest way to do this way *via* student numbers.

Despite these obstacles a significant reduction in anxiety was seen between the beginning of semester one and the beginning of semester two. It was possible that the pre-laboratory activities contributed to the observed difference, but this needed further investigation in the following semesters.
7.3 Results from Semester One 2018

Comparison with 2017: Anxiety and Self-Efficacy About Aspects of Laboratory Work

There were few significant changes from semester one in 2017 to semester one in 2018 among CHEM1002 students. Students reported lower anxiety about working with chemicals, higher anxiety about answering assessed questions and more self-efficacy about both recording data and time management. However, the size of these changes was small. In 2018, all students had completed the pre-laboratory activity. The data from which these results were obtained were filtered to exclude the small number of students with prior experience of a tertiary chemistry unit. The results are presented in table 7.8.

<table>
<thead>
<tr>
<th>Aspect of Laboratory Work</th>
<th>Size (Z)</th>
<th>Significance (p)</th>
<th>Size (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Working with Chemicals</td>
<td>-2.276</td>
<td>0.023</td>
<td>-0.17</td>
</tr>
<tr>
<td>(A) Answering Assessed Questions</td>
<td>2.341</td>
<td>0.019</td>
<td>0.17</td>
</tr>
<tr>
<td>(SE) Recording Data</td>
<td>-2.615</td>
<td>0.009</td>
<td>-0.19</td>
</tr>
<tr>
<td>(SE) Time Management</td>
<td>-3.965</td>
<td>&lt; 0.001</td>
<td>-0.29</td>
</tr>
</tbody>
</table>

The lack of significant changes in the data, combined with the lack of consistency between semester two 2017 and semester one 2018, in which aspects of laboratory work changed from semester one 2017, poses a challenge. This could be interpreted to mean that the pre-laboratory activities had different effects in the different semesters. This method of interpretation would also see the pre-laboratory activities as the cause of the increase in students’ self-efficacy about recording data and time management, and greater anxiety about answering assessed questions. An alternate explanation of the data involves considering that as two different cohorts there may have been pre-existing differences between the levels of CLA and CLSE between the 2017 and 2018 students.
A downside to this approach is that it results in uncertainty as to whether any of the changes were due to the implementation of the pre-laboratory activity. This could be compensated for by administering the CLASEQ both before and after the first pre-laboratory activity to better assess what changes were directly attributable to the pre-laboratory activities. This approach was employed in semester two of 2018.

Correlations Between Anxiety and Self-Efficacy at the Beginning of Semester One 2018

When considering all responses from students at the start of 2018 there were significant ($p < 0.001$) correlations between anxiety and self-efficacy for every aspect of chemistry laboratory work. It was then of interest to consider just those students who had completed surveys at the beginning and end of the semester so that we could see how one subset of the larger cohort changed without introducing the ambiguity of having two different groups of students answering at the beginning and end of the semester. This resulted in fewer significant correlations drawing attention to only those aspects that had the strongest correlations. The significant correlations are summarised in Table 7.9.

Table 7.9: Correlations of anxiety with self-efficacy for aspects of laboratory work at the start of semester 1 2018 ($N = 32$)

<table>
<thead>
<tr>
<th>Aspect of Laboratory Work (Anxiety)</th>
<th>Aspect of Laboratory Work (Self-Efficacy)</th>
<th>Correlation Coefficient ($R$)</th>
<th>Significance ($p$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with Other Students</td>
<td>Working with Other Students</td>
<td>-0.433</td>
<td>0.013*</td>
</tr>
<tr>
<td>Time Management</td>
<td>Recording Data</td>
<td>-0.367</td>
<td>0.039*</td>
</tr>
<tr>
<td>Time Management</td>
<td>Time Management</td>
<td>-0.540</td>
<td>0.001**</td>
</tr>
<tr>
<td>Time Management</td>
<td>Interpreting Data</td>
<td>-0.411</td>
<td>0.020*</td>
</tr>
<tr>
<td>Time Management</td>
<td>Answering Questions</td>
<td>-0.363</td>
<td>0.041*</td>
</tr>
<tr>
<td>Help from Demonstrator</td>
<td>Time Management</td>
<td>-0.417</td>
<td>0.017*</td>
</tr>
<tr>
<td>Help from Demonstrator</td>
<td>Help from Demonstrator</td>
<td>-0.697</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td>Help from Demonstrator</td>
<td>Interpreting Data</td>
<td>-0.414</td>
<td>0.018*</td>
</tr>
<tr>
<td>Interpreting Data</td>
<td>Interpreting Data</td>
<td>-0.370</td>
<td>0.037*</td>
</tr>
<tr>
<td>Answering Questions</td>
<td>Time Management</td>
<td>-0.466</td>
<td>0.007**</td>
</tr>
<tr>
<td>Answering Questions</td>
<td>Interpreting Data</td>
<td>-0.390</td>
<td>0.027*</td>
</tr>
<tr>
<td>Answering Questions</td>
<td>Answering Questions</td>
<td>-0.411</td>
<td>0.019*</td>
</tr>
</tbody>
</table>
There are obvious correlations whereby higher self-efficacy about an aspect of laboratory work and not being as anxious about that aspect. It also makes sense that if students are better at recording data, they will be less anxious about managing time as data collection can take up a large amount of the allotted time for a laboratory session.

The same follows for self-efficacy about interpreting data and answering assessed questions. Students who have high self-efficacy about interpreting data may also be less anxious about asking for help from a demonstrator as they may be less worried about making a mistake in front of the person who will be marking them. Students who have good time management and an ability to interpret data well could be less stressed about answering the assessed questions because they have more time to answer them in and less difficulty interpreting the data necessary to answer these questions. If a student is anxious about asking for help from a demonstrator, they may find it harder to interpret their data or finish on time. Lastly, the lack of correlations with psychomotor aspects suggests skills-based interventions may not be the most effective.

Additionally, given the significant inverse correlation between anxiety about answering assessed questions and self-efficacy about time management, it is curious that there was a significant increase in both from the start of semester one in 2017 to the start of semester one 2018.

Changes in Anxiety and Self-Efficacy During Semester One 2018

In semester one of 2018 a Wilcoxon Signed Rank test was used to investigate if there were significant changes in anxiety or self-efficacy from the start to the end of the semester using paired samples. Unlike the Mann Whitney U test on the independent groups, a Wilcoxon Signed Rank test examines if there is a change in one group of students. This results in greater confidence that any changes seen are not just pre-existing differences between two groups of survey respondents.
Using the Wilcoxon Signed Rank test \((N = 32)\) it was found that there was no significant change in students’ anxiety about: working with chemicals, working with chemical equipment, or working with other students from the start to the end of semester one, 2018. There were significant decreases in anxiety for: recording data \((Z = -2.594, p = 0.009**)\), time management \((Z = -3.139, p = 0.002**)\), asking for help from a demonstrator \((Z = -2.456, p = 0.014*)\), interpreting data \((Z = -1.985, p = 0.047*)\) and answering assessed questions \((Z = -3.076, p = 0.002**).\) Again, using a Wilcoxon Signed Rank test \((N = 32)\) it was found that there was no significant change in students’ self-efficacy about: working with other students, interpreting data or answering assessed questions. There were significant increases in self-efficacy for: working with chemicals \((Z = 2.324, p = 0.020*)\), working with chemical equipment \((Z = 2.446, p = 0.014*)\), recording data \((Z = 3.234, p = 0.001**),\) time management \((Z = 3.383, p = 0.001**\) and asking for help from a demonstrator \((Z = 3.012, p = 0.003**).\) These results are summarised in Table 7.10.

Using a Mann-Whitney U test and both paired and unpaired response from all surveys at given in semester two 2018, it was found that there was a significant \((p < 0.05)\) increase in CLSE and decrease in CLA for most aspects of laboratory work from the start \((N = 108)\) to the end \((N = 41)\) of semester. Exceptions included, CLA about working with chemicals, chemical equipment and other students, and CLSE about working with other students. This decrease in anxiety and increase in self-efficacy during the semester is consistent with the results from previous semesters.
Table 7.10: Changes in students’ anxiety and self-efficacy between the start and end of semester one 2018 (N = 32)

<table>
<thead>
<tr>
<th>Aspect of Laboratory Work (A) = Anxiety, (SE) = Self-Efficacy</th>
<th>Significance (p)</th>
<th>Size (Z)</th>
<th>Size (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Asking a Demonstrator for Help</td>
<td>0.014</td>
<td>-2.456</td>
<td>-0.43</td>
</tr>
<tr>
<td>(A) Recording Data</td>
<td>0.009</td>
<td>-2.594</td>
<td>-0.46</td>
</tr>
<tr>
<td>(A) Answering Assessed Questions</td>
<td>0.002</td>
<td>-3.076</td>
<td>-0.54</td>
</tr>
<tr>
<td>(A) Completing the Work in Time</td>
<td>0.002</td>
<td>-3.139</td>
<td>-0.55</td>
</tr>
<tr>
<td>(A) Interpreting Data</td>
<td>0.047</td>
<td>-1.985</td>
<td>-0.35</td>
</tr>
<tr>
<td>(SE) Working with Chemicals</td>
<td>0.020</td>
<td>2.324</td>
<td>0.41</td>
</tr>
<tr>
<td>(SE) Using Chemical Equipment</td>
<td>0.014</td>
<td>2.446</td>
<td>0.43</td>
</tr>
<tr>
<td>(SE) Recording Data</td>
<td>0.001</td>
<td>3.234</td>
<td>0.57</td>
</tr>
<tr>
<td>(SE) Completing the Work in Time</td>
<td>0.001</td>
<td>3.383</td>
<td>0.60</td>
</tr>
<tr>
<td>(SE) Asking a Demonstrator for Help</td>
<td>0.003</td>
<td>3.012</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Despite a small sample size significant decreases in anxiety and increases in self-efficacy were seen with medium to large effect sizes. This conflicts with previous findings that at UWA anxiety increases during a semester and self-efficacy decreases (Spagnoli et al., 2017). However, it is consistent with the view that during the semester students do the laboratory work and gain mastery experiences. This would be expected to result in an increase in self-efficacy, as was seen for some aspects of laboratory work. One question that remains is why a significant change was only seen for some aspects of laboratory work. Another is what the contribution of the interactive pre-laboratory activities was. An attempt was made to answer the latter question by surveying students before and after completing the pre-laboratory activities in the second semester of 2018.

7.4 Results from Semester Two 2018

Anxiety and Self-Efficacy Pre and Post Pre-Laboratory Activity Completion

In semester two of 2018 the method of evaluation of the impact of the pre-laboratory activities on anxiety and self-efficacy was changed. Instead of comparisons with other groups of students, a Wilcoxon Signed Rank test was used to compare students reports of anxiety and self-efficacy before and after completing the pre-laboratory activities.
The greatest challenge during this semester was how few students were willing to participate in the research project. Not only was the cohort unusually small ($N = 70$, compared to an average size of 249 over the previous 3 semesters) but only 7 of 34 students who completed the pre-laboratory activity completed the post-test. Ethical restrictions meant that students could not receive any marks towards their grade for participating and budget restrictions prevented any real material compensation for the students’ time (except for the interviews but even the chance to win a $40 voucher was not sufficient for more than four students to participate).

As a result, there were only seven paired samples to analyse and it was found that there were no significant differences in the paired data collected before and after the students completed the interactive pre-laboratory activity (except a decrease in self-efficacy about working with chemicals which was unexpected).

Anxiety and Self-Efficacy about Two New Aspects of Laboratory Work

In semester two, 2018, two new aspects of laboratory work were added to the CLASEQ. These were, taking in new information, based on cognitive load theory, and making mistakes, based on an interview with a demonstrator who thought students were very anxious about making mistakes. The data supports this idea as the average anxiety reported by students about making mistakes was 3.4 out of 5.0. This was higher than the anxiety reported for any other aspect of laboratory work.

Furthermore, students’ average self-efficacy about fixing any mistakes they made was 3.0 out of 5.0, which was lower than self-efficacy about any other aspect of laboratory work. On average, students reported higher average self-efficacy about avoiding mistakes ($\bar{x} = 3.3$) than fixing mistakes ($\bar{x} = 3.0$).
Considering cognitive load, students reported an average anxiety of 2.8 out of 5.0, this was less than the average anxiety about making mistakes ($\bar{x} = 3.4$), completing the work in time ($\bar{x} = 3.2$), answering the assessed questions ($\bar{x} = 3.2$), and interpreting data ($\bar{x} = 2.8$). It should be noted that this question was worded as “how anxious are you about feeling overwhelmed?” This wording does not clarify if it is asking about being cognitively or affectively overwhelmed. It could have been phrased in a less ambiguous way. Perhaps, “how anxious are you about not being able to take in all the new information in the laboratory?” The average reported self-efficacy about taking in new information was 3.53 out of 5.0. This was higher than the average reported self-efficacy about fixing mistakes ($\bar{x} = 3.0$), completing the work in time ($\bar{x} = 3.2$), answering the assessed questions ($\bar{x} = 3.3$), avoiding mistakes ($\bar{x} = 3.3$), and interpreting data ($\bar{x} = 3.47$). This suggests that a future intervention which aims to improve students’ self-efficacy in their ability to successfully fix mistakes that they make in the laboratory may be useful.

It also prompts the question of why students are anxious about making mistakes. What is the anticipated negative outcome? Is it that students feel embarrassed when they make a mistake, that it takes time to correct a mistake, some combination of these, or another reason entirely? Given the low anxiety and high self-efficacy reported about asking for help from a demonstrator and the high anxiety and low self-efficacy reported about completing the work in time it seems more likely that the reason is related to time than embarrassment. However, this should be further investigated using qualitative methods.
7.5 Summary

What can be seen from the data collected using the CLASEQ and analysed in SPSS is that an effective survey evaluation of the pre-laboratory activities ought to collect student numbers in order to compare paired samples. That an effective survey evaluation ought to record students’ anxiety and self-efficacy before and after the first pre-laboratory activity is completed, and that an effective survey evaluation would require a larger sample size.

In this way, a survey such as the CLASEQ may be useful as an evaluation strategy to assess the effect of interactive pre-laboratory to reduce students’ chemistry laboratory anxiety and to improve their chemistry laboratory self-efficacy. However, future research will be necessary to demonstrate this. Therefore, future research will also be necessary to quantify the usefulness of these interactive pre-laboratory activities for reducing students’ anxiety and increasing their self-efficacy. It should also be noted that such an approach would only be useful for measuring the direct impact of interactive pre-laboratory activities. A different approach would be required to assess whether the pre-laboratory activities have an indirect effect on self-efficacy or anxiety to reduce students’ chemistry laboratory anxiety and to improve their chemistry laboratory self-efficacy. Such an effect may possibly occur via mastery experiences that occur during the laboratory sessions as a result of students’ preparation using the pre-laboratory activities, but this remains to be seen.
8.0 LIMITATIONS AND FUTURE RESEARCH

Limitations

The first major limitation on this work was the inconsistent sample sizes. While, some surveys were completed by a large percentage of the students, others were not. It was found that the completion rate was higher when students were handed a physical copy of the survey. However, with poor lecture attendance (N = 18, 25.7% in the first week) this was not always viable. The method of sampling immediately before and after students complete the initial pre-laboratory activity showed promise for reducing the effects of independent changes in the subjects over time, an effect called maturation (Cohen & Manion, 1989). However, small sample sizes meant that no significant results were found.

Another limitation relating to survey participation and completion was survey length. Single-item constructs were used to reduce the length of the survey, which was important for several reasons. Firstly, the in-person surveys were completed during class time and it was important not to take too much of this valuable time from students. Secondly, longer surveys have higher rates of non-completion and can lead to survey fatigue (Porter, Whitcomb, & Weitzer, 2004). Students experiencing survey fatigue may cease to answer the questions accurately, instead giving invalid responses (P.-S. D. Chen, 2011). However, while keeping the surveys short was important, the use of single-item constructs restricted the types of analysis that could be done. Additionally, multi-item measures would be more appropriate given how complex constructs in the affective domain are.

Finally, although students thought that the pre-laboratory activities reduced their CLA and increased their CLSE, this is yet to be confirmed by significant changes in the levels of CLA and CLSE reported in the CLASEQ, due to the lack of data from semester two, 2018. This confirmation is necessary as students’ perceptions may have been altered by the Hawthorne or placebo effect (Cohen & Manion, 1989).
Recommendations for Future Research

The first recommendation for future research is to expand the CLASEQ to include multi-item constructs. In this study single-item constructs were chosen to shorten the survey and improve participation. However, this limited the ways in which the data could be analysed, including the preclusion of factor analysis for the additional aspects of CLA and CLSE considered by the CLASEQ. Future research could do a factor analysis on not only these, but also other aspects of laboratory work that students consider important.

Another recommendation is that the power of structural equation modelling be used to investigate what model best fits the relationship between students’ anxiety, self-efficacy, values and pre-laboratory activity completion. A proposed model is given in Appendix N. Within the model in Appendix N, there are references to the value placed on laboratory work by students, this could definitely be an area in which more research is done. Probing the relationship between the aspects of laboratory work valued by students, and the aspects of laboratory work about which students are most anxious. Using structural equation modelling to investigate the mediating effect of self-efficacy, related to perceived control, on this relationship would also be of interest. Also mentioned in the hypothesised model (Appendix N) is the possibility that anticipated aversiveness also contributes to anxiety, alongside anticipated failure (low self-efficacy) in an aspect of laboratory work perceived to be important by the student. The effect of pre-laboratory activities on students’ anticipated aversiveness could also be investigated.

This study also leaves room for investigations into pre-laboratory activities as a way to channel CLA into productive worrying, into the effect of pre-laboratory activities on students’ attitudes towards the laboratory, and into the effect of pre-laboratory activities on other aspects of the affective domain such as motivation. Insights in each of these areas may aide in the improvement of students’ affective experiences in the laboratory.
9.0 CONCLUSIONS AND RECOMMENDATIONS

Conclusions: Summary

In this research project it was initially found that students were most anxious and had least self-efficacy about completing the work in time, answering assessed questions and interpreting data. However, their anxiety reduced, and self-efficacy increased over the semester.

A series of pre-laboratory activities were developed using Adobe Captivate 9 to address the aspects of laboratory work that students were anxious and lacked self-efficacy about. From feedback surveys it was found that Adobe Captivate 9 can be used to make interactive pre-laboratory activities and that students generally agreed these were somewhat helpful to reduce their anxiety and increase their self-efficacy. However, the feedback surveys also revealed that students needed to be made explicitly aware of the pre-laboratory activities available and that technical difficulties needed to be addressed.

In the next generation of pre-laboratory activities, the technical issues were addressed although this involved removing the video content from the interactive activities. In the feedback surveys these pre-laboratory activities received significantly higher scores from students for their anxiety reduction and self-efficacy building than the previous generation. These feedback surveys were generally seen to be consistent with students interview responses. However, some inconsistencies were seen with respect to what aspects of laboratory work students thought were important in their interviews and the literature.

Nevertheless, not only did students perceive the pre-laboratory activities as helpful for increasing their self-efficacy and reducing their anxiety, but the aspects of laboratory work addressed by the activities were generally seen as important by the students.
Furthermore, students were already reporting low CLA and high CLSE about the suggested additional aspect of social interaction.

Students thought the pre-laboratory activities specifically improved their self-efficacy about answering questions, completing the work in time and doing the practical work. They also thought that the pre-laboratory activities were significantly better at reducing their anxiety about various aspects of laboratory work than the assessed pre-laboratory quizzes.

Finally, by using the CLASEQ survey multiple methodology issues were identified and addressed. The last to be addressed with be the small sample size seen in semester two of 2018. Future work will be required to do a measurement of individual students’ anxiety and self-efficacy before and after completing a pre-laboratory activity at the start of the semester. It may also be useful to create multi-item constructs for anxiety, self-efficacy and value regarding each of the aspects of laboratory work so that structural equation modelling can be used to further investigate the relationships between each of these constructs as well as the impact of pre-laboratory activities.

Conclusions: Answers to Research Questions

During the course of this research project it was found that students were most anxious about making mistakes, completing the work in time and answering the assessed questions in the laboratory. Furthermore, these correspond to the aspects of laboratory work were also the aspects of laboratory work that students were least self-efficacious about, which were: fixing mistakes that are made, completing the work in time and answering the assessed questions. There was not only a significant inverse correlation between CLA and CLSE, but also a significant decrease in CLA and increase in CLSE from the beginning to the end of the semester.
Students who completed the pre-laboratory activities developed as an intervention to reduce CLA and increase CLSE did so mostly in order to prepare for the laboratory. Students who did not complete the pre-laboratory activities at the start of the semester generally failed to do so as they were unaware that the activities were available. In contrast, at the end of the semester most students who did not complete the activities failed to do so due to technical issues. These technical issues featured prominently in students’ suggestions for improving the activities. Students also asked for more extensive feedback on their interactions and for a more in-depth explanation of the theory. When the videos were removed due to issues with loading times and playback comments about technical issues dramatically reduced. However, requests for videos to be included increased. Clearly, students think the pre-laboratory activities could be improved by including videos, but only videos that work and do not cause other technical issues.

Students were asked what aspects of laboratory work they thought were important. This was done as control-value theory predicts students will be more anxious aspects about laboratory work that they have low self-efficacy about if they also think that aspect of laboratory work is important. There was some disagreement between students’ survey and interview responses to questions about the importance of various aspects of laboratory work. Furthermore, there was also some misalignment between students’ survey responses and student goals reported in the literature. However, generally students reported that the aspects of laboratory work considered by the pre-laboratory activities were important.

Students generally agreed somewhat that the pre-laboratory activities reduced their CLA and increased their CLSE. There was a significant increase in how helpful the activities were for reducing anxiety and building self-efficacy from the first to the second generation of pre-laboratory activities after the technical difficulties were fixed. As this
coincided with the removal of videos from the activities it suggests that the interactive activities have a positive effect on CLA and CLSE that is not solely due to the effects of modelling skills through videos. Students specifically agreed that doing the pre-laboratory activities improved their self-efficacy about answering questions, completing the work in time, and performing practical skills.

Students reported thinking that the laboratory sessions would be less difficult after they completed the pre-laboratory activities. There was no significant difference between how difficult the students reported thinking the pre-laboratory activities would be after doing the pre-laboratory activities and how difficult the students reported thinking the pre-laboratory activities actually were. Students also reported that the laboratory sessions would have been harder without the pre-laboratory activities.

Nearly 100% of students completed the assessed pre-laboratory quizzes, whereas only about 80% of students completed the unassessed interactive pre-laboratory activities. The vast majority of students who completed the quizzes did so at least in part because they were assessed whereas most students did the pre-laboratory activities purely to prepare. The students thought that the interactive activities were significantly better than the quizzes for reducing their CLA.

Finally, on the whole, students survey and interview results agreed. This triangulation affirms the reliability of the surveys. However, as previously stated there were some discrepancies between the surveys and interviews when it came to the aspects of laboratory work that students thought were important. This could be an area for future research.
Recommendations for Pre-Laboratory Activity Development:

Based on the findings of this study it is recommended that pre-laboratory activities:

1. Develop user-friendly pre-laboratory activities that aim to develop students’ cognitive and psychomotor skills so that they go into the laboratory prepared to gain further mastery experiences.
2. Tailor pre-laboratory activities to address the specific aspects of laboratory work about which student are anxious and lack self-efficacy.
3. Model psychomotor laboratory skills with videos but not in Adobe Captivate 9; instead, create two separate but complimentary resources.
4. Use the basic interactive features in Adobe Captivate 9 to provide students with opportunities to gain mastery experiences in answering the type of questions they will be assessed on.

Recommendations for Pre-Laboratory Activity Evaluation:

Based on the findings of this study it is recommended that further evaluation of the effect of pre-laboratory activities on students’ CLA and CLSE:

1. Ensure a large enough sample size,
2. Collaborate with academics from the school of psychology to improving the design, validity, reliability and utility of any surveys developed to measure affective constructs.
3. Collect data that are both paired and suitable for validation
4. Explore the use of multi-item constructs and structural equation modelling
5. Collect samples of data within the shortest timeframe possible
6. Ask students for feedback via surveys to get representative feedback and via interviews to get a better picture of how individual students are interacting with the resources developed.
Overall, students thought that the pre-laboratory activities reduce their CLA and increased their CLSE. However, they also thought that the activities could still be improved by successfully incorporating videos, and by giving more detailed content and feedback. Therefore, future research should integrate these changes and evaluate how effective the resulting pre-laboratory resources are. This should not only be done by investigating students’ opinions but by also analysing data about the CLA and CLSE reported by students before and after completing the activities.
10.0 REFERENCES


Bates, V. M. (2007). The impact of preparedness, self-efficacy, and math anxiety on the success of African American males in developmental mathematics at a community college. (Doctorate), Morgan State University,


Maul, R. D. (2016). *The effects of gamification using the 5E learning cycle (QuIVERS) on a secondary honors chemistry classroom.* (Master's of Science), Montana State University,


Seery, M. (2017). What is the purpose of practical work?


Participant Information Form

Project title: Modelling Cognitive and Practical Skills in Pre-Laboratory Activities

Name of Researchers: Cara Rummey, Dr. Dino Spagnoli and Dr. Tristan Clemons

Thank-you for considering taking part in this survey, which is part of a research project being conducted Cara Rummey, Dr. Dino Spagnoli and Dr. Tristan Clemons at the University of Western Australia.

This project aims to develop and evaluate interactive pre-laboratory activities to help students prepare for their practical laboratories. Your participation in this study requires you to participate in a survey. This survey will carry no marks towards the unit and should take about 5 minutes. These surveys will provide an opportunity for you to give reflective feedback on the interactive pre-laboratory activities. All data will be used anonymously.

You have been selected to participate in this study because you are enrolled in the chemistry unit CHEM1002 and your involvement is completely voluntary. You may withdraw from the survey at any time. If you agree to participate in the survey, please sign the attached consent form. After the survey responses will be detached from the consent forms and analysed as anonymous data. This means that it will also not be possible to remove your responses from the database set collected should you wish to withdraw them later. If you have any questions, please feel free to contact me at the email address provided below. By signing the participant consent form and participating in the interview you give your consent to be part of this study.

Contacts

If you would like to participate or discuss any aspect of this study, please feel free to contact either Dr. Dino Spagnoli on (work) Ph 0864888681.

Sincerely,
Dr. Dino Spagnoli
dino.spagnoli@uwa.edu.au

Approval to conduct this research has been provided by the University of Western Australia with reference number RA/4/1/9011, in accordance with its ethics review and approval procedures. Any person considering participation in this research project, or agreeing to participate, may raise any questions or issues with the researchers at any time. In addition, any person not satisfied with the response of researchers may raise ethics issues or concerns, and may make any complaints about this research project by contacting the Human Ethics office at UWA on (08) 6488 4703 or by emailing to humanethics@uwa.edu.au. All research participants are entitled to retain a copy of any Participant Information Form and/or Participant Consent Form relating to this research project.
Appendix B: Participant Consent Form

Dr. Dino Spagnoli
School of Molecular Sciences, M310
The University of Western Australia
35 Stirling Highway, Crawley WA 6009
Tel: +61 (0) 6488 8681
Email: dino.spagnoli@uwa.edu.au

Participant Consent Form

Project title: Modelling Cognitive and Practical Skills in Pre-Laboratory Activities

Name of Researchers: Cara Rummey, Dr. Dino Spagnoli and Dr. Tristan Clemons

This survey is designed to help us make better pre-laboratory resources for CHEM1002. It shouldn't take long but please answer as honestly as possible. We're asking for student numbers for analytical purposes only. If we share what we find, so that staff at other universities can use this data to help them make better pre-lab resources, we won't share anything that could be used to identify you. Also, no-one involved in the marking of this unit will know what you personally have said. If you want to know more about the project there is a participant information form on Blackboard, or you can email me (Cara) at 21489383@student.uwa.edu.au.

I have read the participant information and agree to participate in this research, if yes, sign below:

________________________________________________________________________

Contacts:

If you would like to participate or discuss any aspect of this study, please feel free to contact either Dr. Dino Spagnoli on (work) Ph 08 6488 8681.

Sincerely,

Dr. Dino Spagnoli

dino.spagnoli@uwa.edu.au

Approval to conduct this research has been provided by the University of Western Australia with reference number RA/4/1/901, in accordance with its ethics review and approval procedures. Any person considering participation in this research project, or agreeing to participate, may raise any questions or issues with the researchers at any time. In addition, any person not satisfied with the response of researchers may raise ethics issues or concerns, and may make any complaints about this research project by contacting the Human Ethics office at UWA on (08) 6488 4703 or by emailing to humanethics@uwa.edu.au. All research participants are entitled to retain a copy of any Participant Information Form and/or Participant Consent Form relating to this research project.
Appendix C: The CLASEQ

Q1. In the laboratory how anxious are you about:

<table>
<thead>
<tr>
<th></th>
<th>Not at All Anxious (1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>Very Anxious (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with Chemicals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working with Chemical Equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working with Other Students</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recording Data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Completing the work in the Time Given</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asking for Help from a Demonstrator</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Making Mistakes (2018 Onwards)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interpreting Data</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling Overwhelmed (2018 Onwards)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Answering Assessed Questions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q2. In the laboratory how well do you think you are able to:

<table>
<thead>
<tr>
<th>Activity</th>
<th>Not at All (1)</th>
<th>Well (2)</th>
<th>(3)</th>
<th>(4)</th>
<th>Very Well (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work with Chemicals</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Work with Chemical Equipment</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Work with Other Students</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Record Data</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Complete the work in the Time Given</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Ask for Help from a Demonstrator</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Avoid Making Mistakes (2018 Onwards)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Fix Mistakes You Make (2018 Onwards)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Interpret Data</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Take in New Information (2018 Onwards)</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Answer Assessed Questions</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Q3 If you have already chosen a Major to study please specify here (if you are undecided please write N/A):

___________________________________________________________

Q4 Are you a mature-aged student?
   o Yes
   o No

Q5 What gender are you?
   o Male
   o Female
   o Identify Otherwise/Prefer Not to Say

Q6 Is English your first language?
   o Yes
   o No

Q7 Are you in your first year at UWA?
   o Yes
   o No

Q8 What is your highest level of previous chemistry experience?
   o High-School Chemistry
   o Year 11/12 Chemistry
   o Chemistry Unit at UWA
   o Chemistry Unit at Another University

Q6 How aversive was this previous chemistry experience? ___/10
   (10/10 would be the most aversive)

Q7 How aversive do you expect this chemistry unit to be? ___/10
   (10/10 would be the most aversive)
Q8 What grade would you like to get in this unit?
   o  Pass
   o  Credit
   o  Distinction
   o  High Distinction

Q9 What grade do you expect to get in this unit?
   o  Fail
   o  Pass
   o  Credit
   o  Distinction
   o  High Distinction
Appendix D: Means and Standard Deviations of CLASEQ Results at the start of Semester One 2017 for three Level One Chemistry Units

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Efficacy - Working with Chemicals</td>
<td>3.29</td>
<td>178</td>
<td>0.82</td>
</tr>
<tr>
<td>Anxiety - Working with Chemicals</td>
<td>2.81</td>
<td>178</td>
<td>1.28</td>
</tr>
<tr>
<td>Self-Efficacy - Using Chemical Equipment</td>
<td>3.10</td>
<td>178</td>
<td>0.82</td>
</tr>
<tr>
<td>Anxiety - Using Chemical Equipment</td>
<td>2.87</td>
<td>178</td>
<td>1.22</td>
</tr>
<tr>
<td>Self-Efficacy - Working with Other Students</td>
<td>3.67</td>
<td>178</td>
<td>0.91</td>
</tr>
<tr>
<td>Anxiety - Working with Other Students</td>
<td>2.20</td>
<td>178</td>
<td>1.18</td>
</tr>
<tr>
<td>Self-Efficacy – Collecting Data</td>
<td>3.12</td>
<td>178</td>
<td>0.91</td>
</tr>
<tr>
<td>Anxiety – Collecting Data</td>
<td>3.13</td>
<td>178</td>
<td>1.27</td>
</tr>
<tr>
<td>Self-Efficacy – Completing Work in Time</td>
<td>2.45</td>
<td>178</td>
<td>1.00</td>
</tr>
<tr>
<td>Anxiety – Completing Work in Time</td>
<td>3.94</td>
<td>178</td>
<td>1.18</td>
</tr>
<tr>
<td>Self-Efficacy – Asking a Demonstrator for Help</td>
<td>3.34</td>
<td>178</td>
<td>1.12</td>
</tr>
<tr>
<td>Anxiety – Asking a Demonstrator for Help</td>
<td>2.67</td>
<td>178</td>
<td>1.34</td>
</tr>
<tr>
<td>Self-Efficacy – Interpreting Data</td>
<td>2.86</td>
<td>177</td>
<td>0.93</td>
</tr>
<tr>
<td>Anxiety – Interpreting Data</td>
<td>3.20</td>
<td>177</td>
<td>1.15</td>
</tr>
<tr>
<td>Self-Efficacy – Answering Assessed Questions</td>
<td>2.81</td>
<td>177</td>
<td>0.83</td>
</tr>
<tr>
<td>Anxiety – Answering Assessed Questions</td>
<td>3.49</td>
<td>177</td>
<td>1.16</td>
</tr>
</tbody>
</table>

Appendix E: Mann-Whitney U Test CLASEQ Results at the Start and End of Semester One, 2017

<table>
<thead>
<tr>
<th></th>
<th>Mann-Whitney U</th>
<th>Z</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-Efficacy - Working with Chemicals</td>
<td>8190</td>
<td>-5.05</td>
<td>&gt; 0.001</td>
</tr>
<tr>
<td>Anxiety - Working with Chemicals</td>
<td>8399</td>
<td>-4.53</td>
<td>&gt; 0.001</td>
</tr>
<tr>
<td>Self-Efficacy - Using Chemical Equipment</td>
<td>7875</td>
<td>-5.48</td>
<td>&gt; 0.001</td>
</tr>
<tr>
<td>Anxiety - Using Chemical Equipment</td>
<td>7546</td>
<td>-5.67</td>
<td>&gt; 0.001</td>
</tr>
<tr>
<td>Self-Efficacy - Working with Other Students</td>
<td>9258</td>
<td>-3.37</td>
<td>0.001</td>
</tr>
<tr>
<td>Anxiety - Working with Other Students</td>
<td>9955</td>
<td>-2.53</td>
<td>0.011</td>
</tr>
<tr>
<td>Self-Efficacy – Collecting Data</td>
<td>8681</td>
<td>-4.27</td>
<td>&gt; 0.001</td>
</tr>
<tr>
<td>Anxiety – Collecting Data</td>
<td>8244</td>
<td>-4.72</td>
<td>&gt; 0.001</td>
</tr>
<tr>
<td>Self-Efficacy – Completing Work in Time</td>
<td>6641</td>
<td>-6.93</td>
<td>&gt; 0.001</td>
</tr>
<tr>
<td>Anxiety – Completing Work in Time</td>
<td>7448</td>
<td>-5.78</td>
<td>&gt; 0.001</td>
</tr>
<tr>
<td>Self-Efficacy – Asking a Demonstrator for Help</td>
<td>7605</td>
<td>-5.59</td>
<td>&gt; 0.001</td>
</tr>
</tbody>
</table>
### Appendix F: Spearman Rho Correlations Between Aspects of CLA and Aspects of CLSE

#### Semester One 2017 Start:

<table>
<thead>
<tr>
<th></th>
<th>R</th>
<th>p</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with Chemicals - Self-Efficacy and Anxiety</td>
<td>-0.428</td>
<td>&gt; 0.001</td>
<td>178</td>
</tr>
<tr>
<td>Using Chemical Equipment - Self-Efficacy and Anxiety</td>
<td>-0.591</td>
<td>&gt; 0.001</td>
<td>178</td>
</tr>
<tr>
<td>Working with Other Students - Self-Efficacy and Anxiety</td>
<td>-0.575</td>
<td>&gt; 0.001</td>
<td>178</td>
</tr>
<tr>
<td>Collecting Data - Self-Efficacy and Anxiety</td>
<td>-0.523</td>
<td>&gt; 0.001</td>
<td>178</td>
</tr>
<tr>
<td>Completing Work in Time - Self-Efficacy and Anxiety</td>
<td>-0.585</td>
<td>&gt; 0.001</td>
<td>178</td>
</tr>
<tr>
<td>Asking a Demonstrator for Help - Self-Efficacy and Anxiety</td>
<td>-0.528</td>
<td>&gt; 0.001</td>
<td>178</td>
</tr>
<tr>
<td>Interpreting Data - Self-Efficacy and Anxiety</td>
<td>-0.528</td>
<td>&gt; 0.001</td>
<td>177</td>
</tr>
<tr>
<td>Answering Assessed Questions - Self-Efficacy and Anxiety</td>
<td>-0.557</td>
<td>&gt; 0.001</td>
<td>177</td>
</tr>
</tbody>
</table>

#### Semester One 2017 End:

<table>
<thead>
<tr>
<th></th>
<th>R</th>
<th>p</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working with Chemicals - Self-Efficacy and Anxiety</td>
<td>-0.432</td>
<td>&gt; 0.001</td>
<td>133</td>
</tr>
<tr>
<td>Using Chemical Equipment - Self-Efficacy and Anxiety</td>
<td>-0.501</td>
<td>&gt; 0.001</td>
<td>133</td>
</tr>
<tr>
<td>Working with Other Students - Self-Efficacy and Anxiety</td>
<td>-0.473</td>
<td>&gt; 0.001</td>
<td>133</td>
</tr>
<tr>
<td>Collecting Data - Self-Efficacy and Anxiety</td>
<td>-0.563</td>
<td>&gt; 0.001</td>
<td>133</td>
</tr>
<tr>
<td>Completing Work in Time - Self-Efficacy and Anxiety</td>
<td>-0.656</td>
<td>&gt; 0.001</td>
<td>133</td>
</tr>
<tr>
<td>Asking a Demonstrator for Help - Self-Efficacy and Anxiety</td>
<td>-0.638</td>
<td>&gt; 0.001</td>
<td>133</td>
</tr>
<tr>
<td>Interpreting Data - Self-Efficacy and Anxiety</td>
<td>-0.607</td>
<td>&gt; 0.001</td>
<td>133</td>
</tr>
<tr>
<td>Answering Assessed Questions - Self-Efficacy and Anxiety</td>
<td>-0.567</td>
<td>&gt; 0.001</td>
<td>133</td>
</tr>
</tbody>
</table>
Appendix G: Feedback Survey Distributed After the First Pre-Laboratory Activity in Semester Two 2017

Q1. Did you do the interactive pre-lab activity?
   O Yes   O No

If yes, go to question 3. If no, answer question 2 and do not answer questions 3-9.

Q2. Why didn’t you do the interactive pre-lab?
______________________________________________________________

Q3. How long did the interactive pre-lab activity take to load?
   O Not Long   O A While   O A Very Long Time

Q4. Did the videos in the interactive pre-lab activity work? (not the YouTube video)
   O Yes   O No

Q5. Was the interactive pre-lab activity interesting?
   O Yes   O No

Q6. Did the interactive pre-lab activity help you prepare for the lab?
   O Yes   O No

Q7. Will you do the interactive pre-lab activities again?
   O Yes   O No

Q8. How confident are you about your ability to do well in practical laboratories?
   O Not At All Confident   O Somewhat Confident   O Very Confident

Q9. How concerned are you about your ability to do well in practical laboratories?
   O Not At All Concerned   O Somewhat Concerned   O Very Concerned

Q9. Do you have any more feedback for us about the interactive pre-lab activity?

______________________________________________________________________

______________________________________________________________________

______________________________________________________________________
Appendix H: Feedback Survey Distributed After the Final Pre-Laboratory Activity in Semester Two 2017

Q1 Did you complete the Acids and Esters Synthesis pre-laboratory activity?
   o Yes
   o No

Q2 Why did you not do the pre-laboratory activity?
   o I was already prepared
   o Technical difficulties
   o I did not think it would help
   o I was unwell
   o Other

In the following questions you will be asked about the various pre-laboratory activities. Please answer based on the INTERACTIVE activities where possible.

Q3 Before completing the pre-laboratory activity how difficult did you think the practical laboratory would be?

<table>
<thead>
<tr>
<th></th>
<th>Extremely easy (1)</th>
<th>Moderately easy (2)</th>
<th>Neither easy nor difficult (3)</th>
<th>Moderately difficult (4)</th>
<th>Extremely difficult (5)</th>
<th>Don't Remember (6)</th>
<th>Did not complete the pre-laboratory activity. (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Molecular Models</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Benzophenone Reduction</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Acids and Esters Synthesis</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>
Q4 After completing the pre-laboratory activity how difficult did you think the practical laboratory would be?

<table>
<thead>
<tr>
<th></th>
<th>Extremely easy (1)</th>
<th>Moderately easy (2)</th>
<th>Neither easy nor difficult (3)</th>
<th>Moderately difficult (4)</th>
<th>Extremely difficult (5)</th>
<th>Don't Remember (6)</th>
<th>Did not complete the pre-laboratory activity. (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzophenone Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acids and Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q5 How difficult do you think the practical laboratory sessions were?

<table>
<thead>
<tr>
<th></th>
<th>Extremely easy (1)</th>
<th>Moderately easy (2)</th>
<th>Neither easy nor difficult (3)</th>
<th>Moderately difficult (4)</th>
<th>Extremely difficult (5)</th>
<th>Don't Remember (6)</th>
<th>Did not complete the laboratory activity. (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzophenone Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acids and Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q6. How difficult do you think the practical laboratory sessions would have been without the pre-laboratory activities?

<table>
<thead>
<tr>
<th></th>
<th>Extremely easy (1)</th>
<th>Moderately easy (2)</th>
<th>Neither easy nor difficult (3)</th>
<th>Moderately difficult (4)</th>
<th>Extremely difficult (5)</th>
<th>Don't Remember (6)</th>
<th>Did not complete the laboratory activity. (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzophenone Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acids and Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q7. The pre-lab activities stimulated my curiosity for the practical session:

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree (1)</th>
<th>Disagree (2)</th>
<th>Neither Agree nor Disagree (3)</th>
<th>Agree (4)</th>
<th>Strongly agree (5)</th>
<th>Don't Remember (6)</th>
<th>Did not complete the pre-lab activity. (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzophenone Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acids and Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q8. I felt encouraged to learn by the pre-lab activities:

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree (1)</th>
<th>Disagree (2)</th>
<th>Neither Agree nor Disagree (3)</th>
<th>Agree (4)</th>
<th>Strongly agree (5)</th>
<th>Don't Remember (6)</th>
<th>Did not complete the pre-lab activity. (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzophenone Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acids and Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q9. I felt confident in using knowledge acquired from the pre-lab activities to solve problems in the practical class:

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree (1)</th>
<th>Disagree (2)</th>
<th>Neither Agree nor Disagree (3)</th>
<th>Agree (4)</th>
<th>Strongly agree (5)</th>
<th>Don't Remember (6)</th>
<th>Did not complete the pre-lab activity. (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzophenone Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acids and Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q10, the pre-lab activity left room for me to make my own discoveries in the practical session:

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree (1)</th>
<th>Disagree (2)</th>
<th>Neither Agree nor Disagree (3)</th>
<th>Agree (4)</th>
<th>Strongly agree (5)</th>
<th>Don't Remember (6)</th>
<th>Did not complete the pre-lab activity. (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzophenone Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acids and Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q10 I had access to adequate preparation material on Blackboard before the practical class:

<table>
<thead>
<tr>
<th></th>
<th>Extremely adequate (1)</th>
<th>Somewhat adequate (2)</th>
<th>Neither adequate nor inadequate (3)</th>
<th>Somewhat inadequate (4)</th>
<th>Extremely inadequate (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzophenone Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acids and Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Q11, I received adequate feedback on my performance in the interactive pre-lab activities:

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree (1)</th>
<th>Disagree (2)</th>
<th>Neither Agree nor Disagree (3)</th>
<th>Agree (4)</th>
<th>Strongly agree (5)</th>
<th>Don't Remember (6)</th>
<th>Did not complete the pre-lab activity. (7)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzophenone Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acids and Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q12, Preparing for the laboratory made me less anxious about the practical session:

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q13 Doing the interactive pre-laboratory activities generally made me less anxious about the practical session:

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree

Q14 Doing the online quizzes generally made me less anxious about the practical laboratory session:

- Strongly disagree
- Somewhat disagree
- Neither agree nor disagree
- Somewhat agree
- Strongly agree
Q15 How likely are you to do the following:

<table>
<thead>
<tr>
<th>Extremely likely (1)</th>
<th>Somewhat likely (2)</th>
<th>Neither likely nor unlikely (3)</th>
<th>Somewhat unlikely (4)</th>
<th>Extremely unlikely (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spend a lot of time BEFORE the lab worrying about how bad it will be if it does not go well.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Spend a lot of time BEFORE the lab thinking about whether it is likely to go well.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Spend a lot of time BEFORE the lab thinking about how to ensure it goes well.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Q16 How likely are you to do the following:

<table>
<thead>
<tr>
<th>Extremely likely (1)</th>
<th>Somewhat likely (2)</th>
<th>Neither likely nor unlikely (3)</th>
<th>Somewhat unlikely (4)</th>
<th>Extremely unlikely (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spend a lot of time AFTER the lab worrying about how bad it will be if it did not go well.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Spend a lot of time AFTER the lab thinking about whether it went well.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Spend a lot of time AFTER the lab thinking about how to ensure future labs go well.</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

Q17 Would you add anything to the interactive pre-labs for the following labs: Acids and Bases, Benzophenone Reduction, Acids and Esters Synthesis?

________________________________________________________________

Q24 Would you remove anything from the interactive pre-labs for the following labs: Acids and Bases, Benzophenone Reduction, Acids and Esters Synthesis?

________________________________________________________________
Q25 Would you change anything in the interactive pre-labs for the following labs: Acids and Bases, Benzophenone Reduction, Acids and Esters Synthesis?

Appendix I: Interview Two Prompts Semester Two 2017

Q1 Before the interactive pre-lab how difficult did you think the lab would be?

Q2 Did you do the interactive pre-labs?

Q3 Did the interactive pre-labs prepare you for the labs?

Q4 Were the interactive pre-labs user-friendly?

Q5 Did the interactive pre-labs stimulate your curiosity?

Q6 Did the interactive pre-labs provide adequate information about the lab?

Q7 Did the interactive pre-labs motivate you to learn?

Q8 Did the interactive pre-labs help you confidently explore ideas in the practical lab?

Q9 Did the interactive pre-labs help you to learn the theory behind the lab?

Q10 Did the interactive pre-labs help you have a clear mind during the lab?

Q11 Did the interactive pre-labs give you adequate feedback?

Q12 After the interactive pre-lab how difficult did you think the lab would be?
Thank you for taking part in this survey. The following information outlines a research project being conducted by Cara Rummey, Dr Tristan Clemons and Dr. Dino Spagnoli at the University of Western Australia. Your involvement is completely voluntary. You may withdraw from the survey at any time. The questionnaire will require approximately 10 minutes to complete. If you agree to participate in the survey, please complete the questions that follow. Your responses will not be published individually or with any identifying information. If you have any questions, please feel free to contact any of the researchers at the email addresses provided below.

Dino Spagnoli: dino.spagnoli@uwa.edu.au
Cara Rummey: 21489383@student.uwa.edu.au

Please read the participant information form, which can be found in the same folder on Blackboard as this survey. By filling out this survey you agree that you have read these forms and agree to be a participant in this study.

Q1 Which of the interactive pre-labs did you do? (Check all that apply)

☐ None
☐ Acids and Bases
☐ Nitration by Electrophilic Aromatic Substitution
☐ Reduction of a Ketone to an Alcohol
☐ Acids and Esters Synthesis
☐ Acids and Esters Purification

Q2 What did you like most about labs?

_____________________________________________________________________

Q3 What did you like least about labs?

_____________________________________________________________________

Q4 What do you do to prepare for labs? (Check all that apply)

☐ Watch the Pre-Lab Videos
☐ Do the Interactive Pre-Lab Activity
☐ Do the Pre-Lab Quiz
☐ Read Through the Lab Manual
☐ Do my Own Additional Research
Q5 How strongly do you agree with the following statements?

I felt less anxious about doing the labs after I had done the interactive pre-lab activities.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Doing the interactive pre-lab activities made me feel more confident about my ability to answer the questions in the lab well.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Doing the interactive pre-lab activities made me feel more confident about my ability to complete the lab in the time given.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree

Doing the interactive pre-lab activities made me feel more confident about my ability to do the practical tasks in the lab well.

- Strongly agree
- Somewhat agree
- Neither agree nor disagree
- Somewhat disagree
- Strongly disagree
Q6 Which of these are important to you in the lab? (Check as many as apply)

- Following the Procedure
- Safety
- Putting Theory into Practice
- Gaining Practical Laboratory Skills
- Getting a Good Yield
- Understanding what is happening
- Getting a Good Mark
- Getting the Correct Product
- Other ________________________________

Q7 From most important to least important, rank the following:

1. Following the Procedure
2. Safety
3. Putting Theory into Practice
4. Gaining Practical Laboratory Skills
5. Getting a Good Yield
6. Understanding what is happening
7. Getting a Good Mark
8. Getting the Correct Product
9. Other

Q8 Do you have any other feedback about the interactive pre-laboratory activities? This can include things like: technical difficulties, specific errors, things you would add in, things you would remove, things you would do differently etc.

____________________________________________________________________________________________________
____________________________________________________________________________________________________
____________________________________________________________________________________________________
____________________________________________________________________________________________________
Q9 If you have already chosen a Major to study please specify here (if you are undecided please type N/A):

____________________________________________________________________

Q10 Are you a mature-aged student?
0 Yes
0 No

Q11 What gender are you?
0 Male
0 Female
0 Other/Prefer Not To Say

Q12 Is English your first language?
0 Yes
0 No

Q13 Are you in your first semester at UWA?
0 Yes
0 No

Q14 What is your highest level of previous chemistry experience?
0 Year 11/12 Chemistry
0 Chemistry Unit at UWA
0 Chemistry Unit at Another University

Q15 What grade are you expecting to get in this unit?
0 F (< 50%)
0 P (50-59%)
0 C (60-69%)
0 D (70-79%)
0 HD (> 80%)
Q16 What grade would you like to get in this unit?
- F (< 50%)
- P (50-59%)
- C (60-69%)
- D (70-79%)
- HD (> 80%)

Q17 Are you planning to do a level 2 CHEM unit at UWA
- Yes
- Maybe
- No

Appendix K: Interview Prompts from Semester One 2018

Q1. What do you like most about labs?
Q2. What do you like least about labs?
Q3. Before you get into the lab:
   A. what are you most anxious about?
   B. what are you least anxious about?
Q4. Does what you’re anxious about change when you get into the lab and start working?
Q5. A. how about your lab skills, what are you most confident about your ability to do well before you enter the lab?
   B. what are you least a confident about your ability to do well?
Q6. Does what you’re confident about your ability to do well change when you get into the lab and start working?
Q7. A. what aspects of the labs are important to you for you to be able to do well?
   B. which of these is most important to you?
   C. which of these do you think is most important to the demonstrators?
   D. which of these do you think is most important to the lecturers?
Q8. What do you do to prepare for labs?
   - Does this help you feel less anxious?
   - Does this help you feel more confident about your ability to do well in the labs?
Q9. If, at the start of next year, you had a friend who was doing this unit and was feeling anxious about the labs what would you say to them?
Q10. A. what would make a lab count as “successful” to you?
B, what preparation do you think would be necessary to achieve this?
C, what resources would be helpful to you?
D, what do you think the lecturers see as a “successful” lab?

Q11. Do you feel that the pre-lab activity just gave you the answers for the lab questions?
Q12. Do you feel that the pre-lab activity helped you come up with your own answers to the lab questions?
Q13. Do you have any other feedback about the pre-laboratory activities?

Appendix L: Feedback Survey Semester Two 2018

Please rate your agreement with the following statements from 1 (strongly disagree) to 5 (strongly agree):

I was able to fix any mistakes I made during the labs
1 2 3 4 5

I made a lot of mistakes during the labs
1 2 3 4 5

I was able to take in and process new information during the labs
1 2 3 4 5

Preparing for the laboratory made me less anxious about the practical session
1 2 3 4 5

Doing the interactive pre-laboratory activities made me less anxious about the practical session
1 2 3 4 5

Doing the online quizzes made me less anxious about the practical laboratory session
1 2 3 4 5

Doing the interactive pre-laboratory activities made me more confident about my ability to do well in the practical session
1 2 3 4 5
How did you feel about the mistakes you made during labs?
   o It made me feel bad (anxious, disappointed, frustrated etc.)
   o I see them as unfortunate but unavoidable, so I just move on
   o I see my mistakes as a valuable opportunity to learn
   o I didn't make mistakes

Do you think that feeling anxious about the lab made you perform less well?
   o No, my anxiety motivates me to prepare well and succeed
   o No, it doesn't help but it doesn't get in the way
   o Yeah, I think I’d do the experiments better if I wasn't so anxious
   o Yeah, I think I’d take in the information better if I wasn't so anxious
   o Other (Please Explain) _______________________________________

Do you think being confident about your ability to do well in the labs helps you perform well?
   o Yes, being confident helps me do well in labs
   o Yes, but I don't feel confident and that impairs my ability to do well in labs
   o No, I'm confident, but I don't think it effects my ability to perform well
   o No, I don't feel confident, but I don't think it impacts my ability to do well in labs

Is there anything that we could include in the interactive pre-laboratory activities to help you feel less anxious about the labs and/or more confident about your ability to do well in them?
_________________________________________________________________________
_________________________________________________________________________
_________________________________________________________________________
Which of the online pre-lab quizzes and/or interactive activities did you complete? (Check all that Apply)

<table>
<thead>
<tr>
<th></th>
<th>Lab 1</th>
<th>Lab 2</th>
<th>Lab 3</th>
<th>Lab 4</th>
<th>Lab 5</th>
<th>Lab 6</th>
<th>Don’t Remember</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online Quiz</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>-</td>
<td>☐</td>
</tr>
<tr>
<td>Interactive Pre-Lab</td>
<td>☐</td>
<td>-</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

Why did you complete the quizzes? (Check all that apply)
- They were assessed
- The staff expected us to
- To prepare for the lab
- I was bored/procrastinating
- I didn't complete the quizzes (Why?) ____________________________
- Other (Please Specify) _______________________________________

Why did you complete the interactive activities? (Check all that apply)
- I thought they were assessed
- The staff expected us to
- To prepare for the lab
- I was bored/procrastinating
- I didn't complete the activities (Why?) ____________________________
- Other (Please Specify) _______________________________________

Lab 1 | Lab 2 | Lab 3 | Lab 4 | Lab 5 | Lab 6 | Don’t Remember
The interactive pre-lab activities stimulated my curiosity for the practical session:

1  (Strongly Disagree)  2  3  4  5  (Strongly Agree)  Didn’t Complete Pre-Lab  Don’t Remember

I felt encouraged to learn by the interactive pre-lab activities:

1  (Strongly Disagree)  2  3  4  5  (Strongly Agree)  Didn’t Complete Pre-Lab  Don’t Remember

I felt confident in using knowledge acquired from the pre-lab activities to solve problems in the practical class:

1  (Strongly Disagree)  2  3  4  5  (Strongly Agree)  Didn’t Complete Pre-Lab  Don’t Remember

The pre-lab activity left room for me to make my own discoveries in the practical session:

1  (Strongly Disagree)  2  3  4  5  (Strongly Agree)  Didn’t Complete Pre-Lab  Don’t Remember

I was given adequate preparation material before the practical class:

1  (Strongly Disagree)  2  3  4  5  (Strongly Agree)  Didn’t Complete Pre-Lab  Don’t Remember

I received adequate feedback on my performance in the interactive pre-lab activities:

1  (Strongly Disagree)  2  3  4  5  (Strongly Agree)  Don’t Remember
How could the preparation material provided be improved?
________________________________________________________________________

How could the interactive pre-laboratory activity feedback be improved?
________________________________________________________________________

Before completing the pre-lab activity how difficult did you think the practical laboratory would be?
(Rate your answer from 1 = very easy to 5 = very difficult)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbonyl Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esters Purification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

After completing the pre-lab activity how difficult did you think the practical laboratory would be?
(Rate your answer from 1 = very easy to 5 = very difficult or circle “X” if you did not complete the interactive pre-laboratory activity for that lab or did not complete the lab)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Carbonyl Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Esters Purification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

How difficult do you think the practical laboratory sessions actually were?

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbonyl Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
How difficult do you think the practical laboratory sessions would have been without the pre-lab activities?

<table>
<thead>
<tr>
<th>Activity</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acids and Bases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Molecular Models</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aromatic Substitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbonyl Reduction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esters Synthesis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Would you add anything to the interactive pre-labs?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Would you remove anything from the interactive pre-labs?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Would you change anything in the interactive pre-labs?
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
Appendix M: Interview Prompts Semester Two 2018

What do you like most about labs? Why?
What do you like least about labs? Why?
What do you worry about the most before you go into the lab? Why?
What do you most look forward to about labs? OR What do you hope to get out of labs? Why?

How do feel when you’re in the lab?
- What contributes to these feelings?

What’s the biggest source of stress in the lab?

Do you think that being more confident about your ability to do the labs well makes you less anxious about them? Why/Why Not?

Do you reflect on the lab afterwards or do you just tend to move on?
- If yes, does this reflection tend to be helpful or unhelpful in helping you improve how well you can do future labs?
- Does it make you more confident or more anxious about your ability to do better in future labs?

What lab skills do you think you’ve developed this year? How did you develop them?
Have you grown in your confidence about your ability to do the labs well?
What do you think caused you to grow in/lose confidence in your ability to do the labs well?

What would make a lab count as “successful” to you?
- What preparation do you think would be necessary to achieve this?
- What lab skills would you need?
- What resources would be helpful to you?

What do you think the teaching staff want you to learn from the labs?
How would you change the pre-laboratory activities to help you understand the theory behind the lab?
Do you think the worksheet questions help you to think through the theory behind the lab?
How would you change the pre-lab activities to help you succeed at the practical lab tasks?
If you had a friend who was enrolled in CHEM1002 next year who wasn’t confident that they could do the lab component well what would you suggest they do to improve their confidence?
Would there be any attitudes you’d want to encourage them to have towards the lab?
Appendix N: Hypothesised Model for the Interaction of Students’ CLA, CLSE, Prior Experience, Valuing of Laboratory Work and Pre-Laboratory Completion

- Value Placed on Aspect of Laboratory Work by Student
- Students’ Cognitive and/or Psychomotor Skills Relating to Aspect of Laboratory Work
- Students’ Chemistry Laboratory Self-Efficacy About Aspect of Laboratory Work
- Modelling and Practice Mastery Experiences
- Students’ Chemistry Laboratory Anxiety About Aspect of Laboratory Work
- Students’ Expectations About Aversiveness of the Aspect of Laboratory Work
- Students’ Prior Experience of Aspect of Laboratory Work

A. Both modelling and mastery experiences afforded in pre-laboratory activities are expected to help students develop their skills.
B. Students’ skills are expected to effect their CLSE through the impact of skill on whether mastery experiences are achieved.
C. The modelling and mastery experiences afforded in pre-laboratory activities are also expected to have a direct effect on CLSE.
D. Students’ CLSE, related to their perceived control, is expected to mediate the relationship between value and anxiety.
E. The value placed on an aspect of laboratory work by a student is expected to correlate with CLA about that aspect if the student lacks CLSE.
F. Students’ prior experience of doing a particular aspect of laboratory work is expected to influence their CLSE about that aspect.
G. Prior experience is also expected to predict students’ expectations of how aversive an aspect of laboratory work will be.
H. Students are expected to have higher CLA about aspects of laboratory work that they expect to be more aversive.