Changing expectations *by* ‘Experiencing Chemistry’: Engaging mature age students by using a hands-on approach.

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Abstract

Mature age students returning to study often have low expectations of their capacity to be successful in chemistry. Building self-efficacy is an important aspect of course design in the sciences for mature age students. With minimal background in chemistry many of these students return in the hope of studying in the fields of nursing, biomedicine and the allied health courses. They face a range of hurdles in order to gain confidence in their ability to complete the course. It is common for these students to struggle with the concepts in chemistry, the unfamiliar discourse of the discipline, and fear of what they will be required to undertake in the practical component of the course. This paper describes a study which demonstrated that a specifically designed laboratory experience can change students' perceptions of the subject and build confidence in their ability to handle delicate equipment, make accurate observations and record data, thus changing their expectations about their performance in the course. Over 90% of the 288 mature age students who completed this specifically designed practical laboratory rated it as an excellent learning experience which improved their skills and, contrary to their expectations, resulted in an engaging, enjoyable “hands on” laboratory practical. This study has implications for successfully introducing the practical aspects of chemistry and changing perceptions about capability for students from a range of non-traditional backgrounds.

Introduction

Increasing numbers of mature age students are required to study chemistry as they return to study in the fields of nursing, biomedicine, allied health, engineering and teaching. The driving force behind this recent growth has been the shift to a demand-driven system in higher education in the Australian context, which resulted from the Bradley Review (Bradley, Noonan, Nugent, & Scales, 2008).

The Bradley review promoted higher participation in tertiary education to boost labour force participation and productivity in the economy. Australian Bureau of Statistics data indicate that the percentage of students aged 30-33 years with non-school qualifications entering into bachelor degree programs has risen in New South Wales from 33.1% in 2009 to 40.1% in 2013 (A.B.S. 2013).

This widening participation agenda has created a new pool of prospective students and will continue to attract many new players to the sciences, in particular to chemistry as that is seen as an essential component of the many health courses to which mature age students are attracted. Many of these students often face a range of hurdles as they return to study. There are challenges in terms of family and employment pressure, and financial problems associated with giving up fulltime employment (Abbott-Chapman, Braithwaite, & Godfrey. 2004).

These hurdles can be further compounded by the fact that a growing number of mature age students have not studied chemistry previously, may have been away from study for some time and often have had less than satisfactory experiences with education. It is common for these students to struggle with the concepts in chemistry and they are fearful of what they will encounter in the laboratory. To those who have never been in a chemistry laboratory before, handling delicate equipment, and then making accurate observations and data recordings, presents as a daunting prospect to their engagement with the subject. For example, Naiker, Wakeling and Aldred (2013) note “many students showed initial signs of apprehension about entering the chemistry laboratory and often doubt their ability to successfully undertake practical activities.” This ‘lab stress’ is understandable as mature-age students and even recent school leavers often struggle with the discourse of a new discipline. As a result, they feel overwhelmed by the task of combining the theoretical with the practical and hence display considerable apprehension about performing practical laboratory skills. (Bridgeman, Rutledge, Todd 2006). Further Bridgeman, et al (2006) state that “engaging students in their chemistry studies is an ongoing issue across the globe especially as classes become increasingly large and diverse.”

Gulacar & Bowman (2014) state that “Teaching cannot begin until student difficulties with a subject are understood.” Therefore understanding the learning needs of mature age students who have no background in chemistry was the key to the design of this practical laboratory and the impetus for developing an engaging experience. To become engaged students need to feel that they can ‘buy into’ a course. That is, they feel that if they invest time and energy into their learning they will be able to achieve the required learning objectives. When students feel positive about the subject they are more likely to engage in the learning process and become motivated to learn.

Research by Trigwell, Ellis, and Han (2012) indicated that students who were engaged, experienced higher positive emotions, deep learning strategies and achieved higher learning outcomes. For chemistry educators, it is paramount to consider how students feel about the course, their level of engagement with the subject and their belief in their ability to succeed in the course. This means what students believe about themselves as learners is very important. In summary once, students feel they have control over their learning processes they develop greater confidence and a stronger commitment to learning (Lindstrom & Sharma, 2010; Zepke & Leach, 2010).

The importance of practical laboratory exercises

Much literature exists on pedagogically valuable laboratory practical activities where the focus is on the technical aspects of the laboratory and the importance of whole of curriculum strategies to ensure positive learning outcomes for students. (Eilks & Byers, 2010; George et al., 2009; Hofstein & Lunetta, 2004; Kelly & Finlayson, 2007, Reid & Shah, 2007).

It should also be paramount that the laboratory practical be designed so that the students fully engage, enjoy and gain confidence from the ‘hands on’ active learning offered by the experience.

Another important aspect in the design should be the practising of skills as a group. By completing the tasks as a group, the students create a shared connected learning environment, which in turn enhances the quality of the learning. Students who belong to a group see themselves as more engaged both academically and socially and persist at a substantially higher rate than do comparable students in the traditional curriculum (Tinto, 2002).

However, for students who have never been in a laboratory, Sere (2002) comments “with little understanding of the purpose of the apparatus and procedures and what they should observe and measure from the practical, students are not able to engage meaningfully in laboratory work”. With this in mind, it is critical to ensure that the laboratory practical is designed to deliver maximum benefit for the students.

The aim of this study was to develop and test a chemistry laboratory practical specifically designed to engage foundational-level students and then to analyse the survey responses of the students based on their experience in order to:

- Determine whether one specifically designed laboratory practical can engage a diverse group of mature age students with limited experience in a laboratory;
- Investigate if mode of attendance, full time or part time, has any impact on the level of student engagement with the laboratory.

- Investigate students' perceptions of the learning experience as being worthwhile or otherwise.

Context

The Open Foundation program is an open-access program which offers pre-university courses to mature age students who subsequently gain entry to and undertake undergraduate study. There are no prerequisites or entry requirements other than a minimum age requirement of 20 years.

The Introductory Chemistry course offered a purely theoretical approach to chemistry consisting of lectures and tutorials. It was considered that the students would not have had enough experience to engage and therefore benefit from having a practical laboratory exercise included in the course. Conversely, to make a more successful transition into undergraduate chemistry it is necessary to provide the students with the opportunity to develop some elementary laboratory skills. Therefore, a structured multi-task laboratory practical was designed to develop these skills, build confidence and engage with concepts in a stress-free way. Currently, this is the only practical laboratory session these students perform prior to entering into their undergraduate study. For this reason this laboratory practical needs to be a worthwhile exercise for the students as well as deliver a positive message about the value and effectiveness of laboratory work.

Methodology

In order to ensure that the laboratory practical would be appropriate for these students, it was decided to utilise an ASELL (Advancing Science by Enhancing Learning in the Laboratory) workshop. This is a trialled and tested methodology where academics in the discipline come together to assess a series of laboratory experiments and perform an educational analysis of the design and outcomes of the laboratory experiment. The ASELL project 'brings together expertise and resources to develop a collection of experiments across the sciences which facilitate student learning, taking into account variations in student differences (Yeung et al., 2011).

This approach involves two phases of review: (1) testing in a workshop, (2) surveying the originating University. ASELL provides a suite of instruments that are used to gauge the student perceptions of the laboratory experience (Buntine & Read, 2007; Jamie et al., 2007; Yeung et al., 2011).

In the first phase of review, the laboratory practical was presented at an ASELL workshop at the University of Sydney where a group of six academics and two students undertook the laboratory practical and completed a survey afterwards. The survey was designed to gather information on the individuals' experience of the experiment, the implementation of the experiment away from the originating university and the educational intent of the laboratory practical experiment.

Feedback and comments from the workshop indicated that the laboratory would support the development of some elementary laboratory skills. More importantly, the workshop respondents commented that the experiment should help build confidence in students with little or no background in chemistry. The laboratory practical was considered to be pedagogically sound and to be an excellent way to demonstrate the link between the practical and the theoretical in the context of the course and the cohort.

> "*This lab is fun, builds confidence in lab skills and the application of basic theoretical concepts to the practical. For example using equations to describe observed reactions*."

The design of the laboratory practical

The students were required to carry out six chemical reactions plus one modelling exercise and to record all observations. The reactions included 1) Metal plus an acid 2) Acid plus carbonate 3) Precipitation reaction 4) Decomposition 5) Neutralisation 6) Endothermic reaction vs exothermic reaction. Balanced equations for the reactions were to be recorded accurately by listing the states of the reactants and products (e.g. g, s, aq) using correct formulae.

Each activity within the practical takes approximately 15 minutes and one modelling activity takes 10 minutes. Groups of 3-4 students move from one station to the next and complete all activities in close to 100 minutes. The laboratory was designed as a skill-based set of short activities, sometimes referred to in the literature as a ‘recipe-based’ laboratory and is not designed as an enquiry-based exercise. For these pre-university students, “the inputs of information in the first laboratory are huge” and the “ability to plough through a recipe experiment line by line can be regarded as a major achievement in such circumstances” (Bennett & O'Neale,1998,p.60).

The primary aim is to support students as they gain confidence in laboratory work and begin to confirm the theory they have covered in lectures (Buck, Bretz, & Towns, 2008).

Students at the originating university

A cohort of 288 students completed the laboratory practical in the last week of semester, having completed the 12 week Introductory Chemistry course. The sample consisted of full time students (N=145) and part time students (N =143). In both cohorts, the age range was 20-40 years. Students were asked to complete the ASELL Student Laboratory experience survey (ASLE) immediately after completing the laboratory practical. A total of 284 students completed the survey, including the open ended questions, resulting in a return rate of 97%.

Instrumentation

Data was collected using the ASLE Survey. ASLE asks students to respond to 14 five-point Likert-scale and 5 open-ended questions. Items 1-12 are given a Likert scale from ‘strongly agree’ to ‘neutral’ to ‘strongly disagree’. Item 13 asks about the time available for the experiment and is given a Likert scale from ‘way too much’ to ‘about right’ to ‘nowhere near enough’. Item 14 asks about the overall laboratory experience and is also given a Likert scale from ‘excellent’ to ‘average’, ‘poor’ to ‘very poor’.

In order to obtain qualitative data students were asked to comment on the following aspects of the experiment; whether they enjoyed the experience (question 15), what was the main lesson to be learned from the experiment (question 16) what aspects of the experiment were the most enjoyable and interesting (question 17) what aspects of the experiment need improvement and what changes would you suggest (question 18) and finally students were asked to provide any additional comments (question 19). These qualitative responses were analysed using a thematic analysis method outlined in Buntine and Read (2007).

Results

Table 1 below compares the responses of full-time and part-time students for items 1-12. The percentages for strongly agree/agree are combined to provide overall agreement and strongly disagree/disagree are also combined to provide overall disagreement.

Table 1

Percentage of Part time and Full time student responses to items 1-12 on the ASLE

Items 1-12	Part time students			Full time students		
	SA/A	N	D/SD	SA/A	N	D/SD
1. This experiment has helped me to develop my data interpretation skills	92%	6%	1%	91%	8%	1%
2. This experiment has helped me to develop my laboratory skills	96%	4%	0%	97%	3%	0%
3. I found this to be an interesting experiment	95%	4%	1%	96%	4%	0%
4. It was clear to me how this laboratory exercise would be assessed	97%	3%	0%	93%	7%	0%
5. It was clear to me what I was expected to learn from completing this experiment	96%	4%	0%	94%	6%	0%
6. Completing this experiment has increased my understanding of chemistry	90%	9%	1%	90%	9%	1%
7. Sufficient background information, of an appropriate standard, is provided	94%	6%	0%	92%	8%	1%
8. The demonstrators offered effective support and guidance	99%	1%	0%	98%	2%	0%
9. The experimental procedure was clearly explained in the lab manual or notes	97%	3%	0%	95%	5%	0%
10. I can see the relevance of this experiment to my chemistry studies	98%	2%	0%	97%	2%	1%
11. Working in a team to complete this experiment was beneficial	97%	3%	0%	94%	5%	1%
12. The experiment provided me with the opportunity to take responsibility for my own learning	97%	3%	0%	94%	6%	0%

Over 90% of all part-time and full-time students agreed that the experiment helped to develop their laboratory skills. Chi-squared analysis confirmed that the distribution of student ratings between the two groups of students was not significantly different: $\chi^2 = 0.80$ df =2 p=0.67.

Over 98% of both full-time and part-time students agreed that ‘the demonstrators offered effective support and guidance’, also that ‘I can see the relevance of this experiment to my chemistry studies’, and ‘this experiment has helped me to develop my laboratory skills’.

The Likert for item 13, the time available to complete the experiment, was “about right” for 82% of both cohorts. For Item 14, over 90% of students rated the experiment an excellent or a good learning experience. There was no significant difference in students’ ratings for overall learning experience between part-time and full-time students. Chi-squared analysis confirmed that the distribution of student ratings between the two groups of students was not significantly different: $\chi2 = 0.056$ df =2 p=0.97.

Students’ responses to open-ended questions

A total of 284 students submitted responses to the open ended questions (Table 2).The comments were classified according to identified broad themes and whether the content of comments was positive or negative in relation to that theme.

In response to the question ‘What was the main lesson to be learned from the experiment?’ 145 students commented that it was the experimental techniques and skills, specifically ‘accurate observation and recording’, that were the main lessons to be learned.

Table 2
Summary of categories used in content analysis of the ASLE Open response items

Category Name	**Total Comments**	**Sub Categories**
Interest and engagement (IE)	232	Enjoyable experience (42) Great first experience in a lab (56) Better than sitting in lectures (24) Easy to follow instructions (12) Alleviated fear of laboratory (56) Interesting stress-free way to learn chemistry (42)
Kinaesthetic. Hands on/ Visual (K)	146	Building molecular models (26) Seeing/hearing reactions (38) Visual aid to understanding chemical changes (41) Feeling the temperature change in the test tube (19) Watching the speed of reactions (22)
Understanding of chemistry (UC)	128	Techniques for identify different gases (21) Now I understand isomers (18) Using balanced equations to describe observations (27) Chemicals react to form new substances (18) Energy is released in chemical reactions (3) How a catalyst works (19) Different classes of reactions (22)
Experience of experiment (EE)	145	Laboratory skill improvement (41) Handling scientific apparatus (32) Accurate observation and recording (27) Correct laboratory safety procedures (21) Critical thinking (3) Following instructions (5) Collecting gases (16)
Teamwork (TW)	19	Appreciation of help from classmates (5) Great to interact and share ideas (3) More efficient use of time as a team (11)
Potential for Improvement (PI)	20	More experimental stations (3) More time for experiments (9) Less time for experiments (3) More lab sessions (3) More complex experiments (2)
Miscellaneous (M)	23	Supportive demonstrators (20) Pre-read lab notes (1) Importance of PPE (1) Enjoyed oral questions (1)

Discussion

One of the questions posed for this study was whether the student mode of attendance had any impact on the level of engagement. The analysis of the Likert scale responses indicated that there was no statistically significant difference between full- time and part-time students despite the latter having to complete the laboratory practical session on an evening and often after a full day at work elsewhere.

Analysis of students' comments in the open response section of the survey highlighted several main themes which are discussed further.

Engagement and Interest

Students' responses indicated recognition of the value of the practical application and its relevance to their study in chemistry and as a result were able to participate in a meaningful way, increasing their engagement with the subject and changing their expectations about their ability to perform the laboratory tasks. The 'interest and engagement' category received the most comments (232) overall in the open-response questions.

Contrary to the findings by Sere (2002) discussed earlier, that students with little understanding of the purpose of the apparatus and procedures were unable to engage, this study was able to demonstrate that a specifically designed laboratory practical can provide a meaningful learning experience for students with a limited background in the subject.

By completing the chemical equations for the observed reactions, the students were able to link the practical with the theoretical and therefore demonstrate their knowledge of chemistry. This in turn, built confidence in their ability to undertake more complex tasks, with over 96% responding that they felt they had improved their laboratory skills. Successful completion of the laboratory practical encouraged students to reflect on their learning and the majority of students felt that they had been given the opportunity to take responsibility for their own learning. The students were able to consolidate the theory they had covered in lectures and organise this theory based on the practical applications they had been able to perform. As a result, over 90% of both the part time and the full time cohorts rated the practical experience as an excellent or good learning experience.

Supportive demonstrators
99% of the students were in overall agreement that supportive demonstrators offered effective guidance. It appears that the interaction between demonstrators and students had a substantial impact on the positive nature of the experience and level of engagement. This is an indication of the value of excellent interaction and support, as well as the importance of a scientific conversation as a valuable learning tool. This aspect of the laboratory practical experience could be examined further in future research to see whether this is an effective form of assessing student knowledge.

Teamwork
Specific comments about teamwork were limited to 19 students, however 97% of the part time and 94% of the full time students were in overall agreement that 'working in a team to complete this experiment was beneficial'. By practising elementary skills as a group in the laboratory the students were able to create a shared learning environment which in turn enhanced the quality of the learning (Tinto, 2002).

Kinaesthetic
There were a large number of student responses (146) in the 'kinaesthetic hands-on/visual' category which indicate a high level sensory appreciation for the speed of reactions, the rapid measurable temperature changes and the colour changes.

Experience of an Experiment
There were 145 comments about the practical aspects of performing the experiments such as developing scientific thinking skills in observation and data collection and identifying chemical hazards and risks.

Conclusion and Implications
The primary educational objective of this laboratory practical was to engage students and provide the opportunity to practice elementary laboratory skills while gaining confidence in the laboratory setting.

The results indicate that a well-designed practical laboratory can be an engaging, positive experience and should be incorporated in the range of pedagogical tools that can be used to inspire mature age students to learn about the practical aspects of chemistry. Qualitative comments were positive and over 90% of the responding students were in overall agreement with the statement that this was an excellent/good learning experience.

The analysis of the experiment using the ASELL methodology ensured that the experiment was appropriate for the student cohort and provided the opportunity to make improvements prior to implementation at the originating institution if necessary.

The educational strength of this laboratory practical is that it represents a successful approach to the introduction of the role of the chemistry practical experience as an enjoyable learning tool which can increase engagement for pre-university mature age students. By understanding the challenges facing mature age students returning to study in the sciences and incorporating changes in pedagogy to address those needs, the study of chemistry becomes more accessible to a wider community.

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