The influence of student engagement with online pre laboratory work modules on academic performance in first year chemistry

Alexandra Yeung and **Siegbert Schmid**, School of Chemistry, The University of Sydney
Roy Tasker and **Janine Miller**, School of Science, Food and Horticulture,
University of Western Sydney
a.yeung@chem.usyd.edu.au s.schmid@chem.usyd.edu.au r.tasker@uws.edu.au
j.miller@uws.edu.au

Introduction

Information and communications technologies are increasingly being incorporated into teaching activities in higher education. They offer the opportunity to improve student learning experiences provided they are used in an educationally sound way. This may be through triggering student interest, improving engagement and, in turn, helping students to develop a deeper understanding of particular concepts. A previous study examined students' engagement with two specific online pre-laboratory work modules to determine how students engage with them, and correlate this engagement with learning style (Tasker, Miller, Kemmett and Bedgood Jnr 2003). The present study extends that work with a broader range of students and on a much larger scale, to investigate the claim that student engagement with these modules improves academic performance in first year chemistry.

Pre-laboratory work modules

Both online modules considered in this study are from *Bridging to the Lab: Media Connecting Chemistry Concepts with Practice* (Jones and Tasker 2002). Each module is set in the context of a real life problem, which students solve in a virtual environment. The modules can be used as laboratory preparation as they contain simulations, which emphasise aspects of experimental design and allow visualisation of processes and structures at the molecular level. Students make decisions regarding experimental design, observe simulations of reactions (both at macroscopic and molecular levels), record and interpret data, perform calculations, and draw conclusions from their results. Each module is divided into sections and a student can only progress to the next screen once the learning activities have been completed correctly. Feedback is provided to assist students when they make mistakes and they are free to navigate backwards through past sections. A summary is provided at the end of each module, followed by a 'self test' section in which students can test what they have learned by applying their freshly gained knowledge to new situations.

The first module, *Concentration: Preparing a Standard Solution* (hereafter called the standard solution module), requires familiarity with concepts of stoichiometry. Students 'prepare' a standard solution of a particular concentration, including selecting appropriate glassware. The second module, *Reaction Types: Treatment of Copper(II) Waste* (hereafter called the copper(II) waste module), is designed to develop students' qualitative understanding of redox and precipitation chemistry, as well as revising solubility rules. Students are required to make observations and draw conclusions, highlighting the distinction between these activities.

Methodology

Participants

Three different groups of first year chemistry students participated in this study at the University of Sydney in 2004. All students were enrolled in one of the semester 1 chemistry units of study available to students undertaking mainstream science qualifications. All three units cover similar material, but differ in the level of assumed prior knowledge, and the level at which material is presented. CHEM1001 (Fundamentals of Chemistry) students have either not completed chemistry for the Higher School Certificate (HSC), i.e., university entry level, or achieved poor results at that level. They are referred to hereafter as 'non-HSC students'. CHEM1101 (Chemistry 1A) students have satisfactorily completed HSC chemistry ('HSC students'), whilst CHEM1901 (Chemistry 1A - Advanced) students have achieved a HSC chemistry mark above 80 ('Advanced students').

Students from all three groups were asked to complete both online pre-laboratory work modules in their own time. 720 (63 %) and 779 (68 %) students completed the copper(II) waste and standard solution module, respectively. 704 students (62%) completed both modules.

Engagement Measure

Student use of the online modules was monitored. This included tracking progress through each section of the modules as well as recording the timing and nature of every interaction. As a result, the length of time that any screen or feedback box was displayed, choice of navigation style, and the types and order of selections (both correct and incorrect) could be determined.

In order to represent the level of student engagement quantitatively, an 'engagement measure (EM)' was constructed. This was based on measurable criteria, which define engagement in terms of tracking variables that provide evidence of thoughtful reading of text, consideration of possible choices in the click and drag options, and reflection on visual information in animations. Distinct trends in interaction characteristics were identified after examining the interaction patterns of students with the modules. These characteristics were analysed and five parameters were identified for each of the modules that seemed indicative of student engagement. It stands to reason, e.g., that an engaged student would spend time reading the first introduction screen since students were unfamiliar with the modules, and the introduction is needed to place the online learning into context. The choice of parameters was validated by correlating information from stimulated-recall interviews with 16 students, as they described their degree of engagement through the modules, with their interaction data. This technique for deriving the EM was the same as that in the earlier study (Tasker et al. 2003), and similar, not identical, parameters were used.

For the copper(II) waste module the parameters chosen were: total time taken to complete the module; time taken to read the first introduction screen; total time to read the feedback boxes; access of the solubility rules screen; and, time to choose one of six options that best described the observation illustrated by the video image when NaOH was chosen (moderated by the correctness of the choice made). The parameters chosen for the standard solution module were similar to those above. The main difference is the replacement of accessing the solubility rules screen with whether students played animations that illustrate the techniques for making a standard solution.

Once these parameters were chosen engagement limits had to be set so that students' interactions could be categorised. In a first step, the distribution of results for each parameter was plotted (see Figure 1). The upper engagement limit was set as the time after which the frequency becomes approximately constant. The lower engagement limit was determined by estimating the least amount of time that a good student would require to complete the activity. In this example, the engagement limits were set at 5 s and 20 s, corresponding to the range inside the square. On each parameter, disengaged students are scored 0, engaged students are scored 1 and very engaged students are scored 2. A similar process was used to set engagement limits for each of the parameters for both modules.

Following the allocation of scores for each parameter to every student, the scores were summed to give an overall EM for each module. The EM for each module was distributed normally (see Figure 2) as confirmed by statistical calculations. For students who completed both modules a total EM was calculated and also found to be normally distributed.

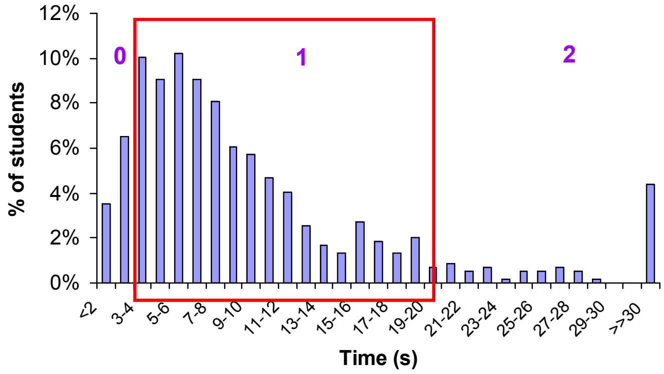

Figure 1. Distribution of times for one parameter

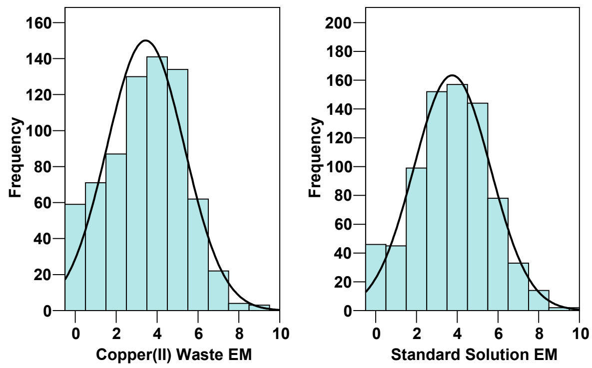

Figure 2. Distribution of EM for (a) copper(II) waste and (b) standard solution modules.

After determining the total EM for all 704 students who completed both modules, students were divided into groups according to engagement and units of study. Students with a total EM below 5 were considered ‘disengaged’, students with a total EM between 5 and 11 were considered ‘engaged’ and students with a total EM over 11 were considered ‘very engaged’.

Results and discussion

One-way ANOVA was conducted to explore the impact of student engagement with the online modules on final exam mark for HSC students. Subjects were divided into treatment groups depending on engagement. It was found that there was a statistically significant difference in academic performance between these treatment groups for HSC students [$F_{2,383}=3.839$, $p=0.022$]. Post-hoc comparisons using the Tukey HSD test indicated significant differences in the mean exam marks for HSC students with different engagement levels. Very engaged and engaged students performed better than those who were disengaged by an average of about six and four marks, respectively. The difference in performance between the engaged and very engaged students did not reach statistical significance. Similar analyses for non-HSC and Advanced students, however, failed to detect a significant correlation of performance with engagement.

HSC students who were engaged or very engaged with the modules performed significantly better in the exam than students who were disengaged. HSC students would have an adequate chemistry background and can appreciate the ideas presented. These prior knowledge structures allow new information to be more easily transferred into long-term memory to be used in the exam as previous understanding allows connections to be made to the new information more easily (Sweller, Van Merrienboer and Paas, 1998). The improved exam performance of engaged students and very engaged students may be explained by the fact that these students are more likely to progress through the modules paying attention to the ideas presented and would be expected to be able to link new information to previous knowledge, thus increasing learning.

Advanced students, however, who were engaged with the modules, did not perform better in the exam than disengaged students. Advanced students have a very good chemistry background and can probably complete the module quickly, which would indicate non-engagement for some of the parameters used in constructing the EM. However, this does not necessarily mean advanced students are not engaged, since these students might not require as much time to complete certain activities. That is one of the limitations of using student timings in determining engagement, as external factors influencing time spent are unknown. Furthermore, since advanced students have a good chemistry background, even a disengaged student may perform as well as an engaged student regardless.

The level of engagement with the online modules did not have a statistically significant correlation with exam performance for non-HSC students. Since non-HSC students have a poor chemistry background, it might be expected that those students who were engaged with the modules would perform better in the exam. Instead the performance of all non-HSC students increased for those doing the modules, irrespective of engagement (Schmid and Yeung, 2005).

The relationship between exam performance and engagement for all three groups can be better understood in terms of the level at which the modules are presented. Advanced students do not get any detectable benefit, HSC students only get a benefit when they are engaged, while non-HSC students benefit regardless of whether or not they are engaged suggesting that these modules match their level of prior understanding. An alternative interpretation takes the determination of the EM into account. The methodology as introduced by Tasker et al. (2003) may not have reached maturity yet. The parameters used to construct the EM were chosen as seemed plausible but there might be other ways. Furthermore, the engagement limits for the various parameters were set following statistical analyses, but these fail to take into account individual circumstances. The previous study found that ~8 % of students who completed the modules were not engaged, while the present study finds ~26 % disengaged students. While the student populations for the two studies were different, this may still reflect a need for further refinement of the methodology. In particular, more student interviews might be required to establish the authenticity of the conclusions.

Conclusion

The link between student engagement with two online chemistry modules and academic performance was investigated. Two possible conclusions from this study are, firstly, that these modules are targeted at the level appropriate to the prior understanding of non-HSC students, and secondly, that the methodology used for the construction of the EM needs further refinement, in particular to better incorporate students' individual circumstances. More interviews with participating students are needed, for example, with a non-HSC student who appeared disengaged with the online modules but did well in the exam. This might help to establish firstly, whether or not they were indeed engaged and secondly, if they were engaged what needed to be changed in the construction of the EM to take that discrepancy into account.

This study has implications for the design and implementation of learning modules of this kind. The modules need to provide the appropriate levels of challenge for students with different levels of prior knowledge and that may well be achieved by providing separate navigation pathways, which allow for prior knowledge to be taken into account.

Acknowledgements
We would like to thank Chris Kemmett at CADRE Design for collecting the module tracking data.

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