Scaffolded Research-Based Learning for the Development of Scientific Communication in Undergraduate Physiology Students

Deanne H. Hryciw and Arianne M. Dantas

Corresponding author: Deanne.skelly@unimelb.edu.au
Department of Physiology, The University of Melbourne, Melbourne, Parkville, VIC 3010, Australia

Keywords: scaffolded learning, science communication, undergraduate

International Journal of Innovation in Science and Mathematics Education, *24*(1), 1-11, 2016.

Abstract

A Research Based Physiology subject was developed to improve undergraduate students' experimental design and written communication skills through the generation of a scientific manuscript. This subject consisted of active-learning lectures, small-group discussions and formative feedback on students' drafts of sections of the manuscript. Students were segregated into low-, middle- and high-achievers based on their prior level of achievement. Analysis was performed on students enrolled in Semester 1 and Semester 2 (n = 332) in 2013. Our data demonstrated that there was a significant positive Kendall's rank co-efficiency between the number of drafts submitted and the scientific manuscript assignment mark for low- and middle-achievers. Furthermore, for these groups, there was a significant positive Kendall's rank coefficiency between students' prior level of achievement and their assignment mark, with no coefficiency between their prior level of achievement and number of drafts submitted. However there was no coefficiency between prior level of achievement and number of drafts submitted for all groups. A significant positive Kendall's rank coefficiency between prior level of achievement and either theoretical content or experimental design marks exists for middle-achievers only. Finally, all groups had a significant improvement in their assignment grade and experimental design marks compared to their prior level of achievement. However only low- and middle-achievers demonstrated an improvement in their theoretical content mark compared to their prior level of achievement. Therefore, this study demonstrates that scaffolded learning using active-learning lectures, small-group discussions and collaborative workshops, may enable students to develop their experimental design skills, but more importantly can be used to develop written scientific communication skills.

Introduction

Scientific communication, as a core competency, has previously been emphasised in the context of undergraduate education (National Research Council, 2003). More recently, employers and the government are specifically focused on the development of scientific written communication skills in undergraduate degrees (*see* ALTC, 2011; DEEWR, 2011; Graduate Outlook Survey, 2013). Traditional science curricula typically are developed to teach discipline content and not scientific literacy skills (Drury and Muir, 2014). Consequently, there is an increasing emphasis on the specific pedagogies that will develop scientific literacy and communication skills. Based on this, science educators have promoted the development of specific scientific communication in the science curriculum, with some researchers focused on modelling effective communication through the critiquing and dissection of scientific manuscripts (Gillen, 2006; Mulnix, 2003). Two key skills imbedded in this are the effective communication and understanding of scientific research (Brownwell et al, 2013). An integral component of the dissemination of scientific advances in scientific manuscripts is the effective use of clear and purposeful language (Pechenik, 2004). Development of scientific written communication skills will also be of benefit to a future career as a scientist, as students' ability to publish manuscripts, prepare reports and obtain grant funding relies heavily on these skills (Tonissen et al, 2014).

Primary scientific literature is a gold standard for the effective communication of scientific data to a specific target audience, and the ability of students to dissect and understand scientific literature is important in the development of their scientific literacy (Kardash, 2000). Particularly, educators believe that scientific manuscripts can help in the development of scientific processing skills (Gillen, 2006) and scientific comprehension (Mulnix, 2003). However, others disagree as they believe that scientific manuscripts are too difficult for undergraduate students to comprehend (Porter, 2005; Smith, 2001). One issue associated with a scientific manuscript as a literacy tool may be that simply teaching students to write a scientific manuscript may not be sufficient in improving their scientific communication skills. Core to the production of a scientific manuscript, students must be provided with the relevant understanding and opportunity to develop their understanding of areas of theoretical content of the manuscript, data analysis and experimental design skills. Potentially, the degree of difficulty in the scientific manuscript task may be associated with a clear lack of understanding of the underlying principles that are fundamental to experimental design, which occurs independently of critiquing scientific language and theoretical content. One additional issue associated with this is that educators have students with varied abilities and learning styles which may reduce the effectiveness of the task. Thus, it has been suggested that diversity in education styles and modes of delivery are important in accommodating students' differences through the use of multiple methods and tasks (Rivard, 2004).

Of importance in any design of an intervention is the key concept that learners' characteristics, such as prior achievement level, which are essential to the success of any interventional programs that are associated with a subject (Lehr and Harris, 1988). A curriculum that emphasized critical thinking, problem-solving and conceptual understanding through communication is believed to be an effective tool for low-achiever students to improve their understanding of complex content and improve scientific literacy (Glatthorn, 1991). Furthermore, others have suggested that peer-instruction, small-group or workshop activities and cooperative learning may enhance the theoretical understanding of low-achievers (Cuban, 1989; Thornburg, 1991). Previous studies have used multiple activities to enhance the learning of students, and specifically identified that low-achievers performed better when a task utilises peer discussion to explain tasks, while high-achievers preferred written tasks to enhance their learning (Rivard, 2004; Rivard and Straw, 2000).

Based upon these previous findings, we have developed a Research-Based Physiology subject, which aims to improve undergraduate students' abilities to communicate science effectively through their development of experimental design, data analysis. To cater for low-, middle- and high-achiever undergraduate students, we employed multiple individual and group tasks using a variety of learning approaches to scaffold the development of a number of skills that will enhance their written scientific written communication skills (Figure 1). These tasks enabled small-group work, discussion and writing to develop scientific communication, theoretical knowledge and experimental design skills across a diverse cohort of students. The Research Based Physiology subject is a component of the 2nd year Bachelor of Science degree that is a core subject for the Physiology major.

Method

Based on the previous studies, our research hypothesis was: Does a scaffolded learning approach support the writing of a scientific manuscript assignment, so that irrespective of their prior achievement levels, students can obtain a high level of achievement?

Participants

Students enrolled in the undergraduate Bachelor of Science degree at The University of Melbourne (Melbourne, Victoria, Australia) participated in this study. Students were in their second year of this degree program. The average age of participants was 19.6 ± 0.8 years and 54% of the participants were female. All students had completed at a minimum the first year of the undergraduate degree. Students enrolled in Research-Based Physiology in either Semester 1 or Semester 2 (332 students) in 2013, were investigated. Students were excluded from this study if they did not submit their assignment task, their mark for the task was penalised for lateness, or their average total mark for each subject completed in their degree thus far (prior level of achievement) was not available.

For the analysis of the study, students were classed as low-achievers if their average prior level of achievement was below 65 (out of a maximum of 100), middle-achievers was between 66 and 79 and high achievers greater than 80. At the University of Melbourne, a mark of 80 or above is the highest level of achievement (H1), while a mark below 65 is equivalent to a pass (P), with a mark below 50 a fail.

Design

Students enrolled in Research Based Physiology undertook a scaffolded learning approach with active-learning lectures, small-group discussions and collaborative work during workshops to develop their experimental design and scientific communication skills. These skills were assessed using a range of formative online learning tasks and a summative scientific manuscript assessment task, as well as an exam designed to assess both their experimental design skills and theoretical content knowledge (Figure 1).

The examination consisted of 20 multiple choice questions and four long answer questions (worth 20 marks each), which addressed their understanding of experimental design and physiological concepts. Of the 12 total lectures taught during the semester, five lectures were focused on experimental design and scientific reporting (hypothesis generation, controls, ethics, protocol design and the structure of the different sections of the manuscript). In these lectures, examples from other scientific manuscripts were used to explicitly teach students best practice and to allow students to critically review the manuscript examples provided. Lectures incorporated the use of an audience response system to choose the best example, with discussion on the limitations of alternative responses also undertaken.

Students also attended four workshops that focused on experimental design and data analysis to develop their scientific comprehension skills. In each workshop students worked in small groups (consistent across the semester, group size = 5 - 7). Discussion was focused on using the knowledge gained in the lectures, to address specific scenario-based questions on the scientific method. For example, students would use their understanding of hypothesis generation and controls to formulate a hypothesis and generate a basic study protocol focused on caffeine use and its effects on heart rate in humans. Students would write their responses to these questions and submit a group assessment task at the completion of these workshops (Figure 1).

Figure 1

Week	Lecture topic	Workshop task with group assessment task	Submitted works (summative (s) or formative (f) assessment from groups (g) or individuals (i))
1	Subject Introduction		
2	Experimental Design	Hypotheses and Controls	Hypotheses and controls (s, g)
3	Respiratory Physiology		Experimental design (s, i)
4	Cardiovascular Principals		Experimental design (s, i)
5	Introduction format and writing		Theoretical content(s, i)
6	Materials and Methods format and writing	Experimental Protocol Design	Introduction Draft (f, i)/ Theoretical content (s, i)
7	Results format and writing	Data Analysis	Materials and Methods Draft (f, i)
8	Abstract and Discussion format and writing	Discussion of Results	Results Draft (f, i)
9	Muscle and Exercise		Abstract and Discussion Draft (f, i)/ Experimental Design (s, i)
10	Cardiovascular Responses in an animal		Experimental design (s, i)
11	Animal and Human Ethics		Scientific Manuscript Assignment / Theoretical content(s, i)
12	Experimental design: cells, tissues or organisms?		Theoretical content(s, i)
Exam			Experimental design / Theoretical content (s) (i)

Figure 1. Subject structure to enhance experimental design and scientific communication. Subject structure for students enrolled in Research Based Physiology at The University of Melbourne. Students were explicitly taught concepts of research design in a lecture format. Students also participated in group workshops to apply their understanding about experimental design and complete scenario-based assessment tasks. Finally students submitted a variety of assessment tasks either individually or in groups to enhance the development of their scientific writing skills.

To assess students scientific communication skills, students individually submitted a scientific manuscript. To assist with the development of their scientific writing skills, individual students were able to voluntarily submit drafts based on the different sections of their final scientific manuscript assignment for formative feedback. The manuscript used data which was generated in the practical class setting from 29-30 student subjects following the same protocol. Students measured respiratory and cardiovascular parameters in a subject exposed to room air, compared to the same subject exposed to either elevated (42°C) or reduced (12°C) temperature. Students enrolled in Research Based Physiology designed the experimental protocol, generated the data, and were explicitly taught how to analyse the data using the basic measurements of mean, standard error of the mean and a paired Students T-test. All students completed the same protocol to allow for data to be generated that could be analysed statistically, and all students submitted the scientific manuscript assignment based on the same data. Assessment criteria for the scientific manuscript assignment included content knowledge, as well as marks allocated to students for conforming to the standards of scientific literacy in a scientific manuscript format.

In addition to the tasks focused on the scientific manuscript, students were taught theoretical physiological content focused on the respiratory and cardiovascular systems. This content provided the basic understanding for the parameters that were measured in the experiment designed by the students. Students submitted assessment tasks focused on their understanding of the respiratory and cardiovascular systems after performing basic laboratory tests such as spirometry and blood pressure measurements. Marks for these tasks were not considered for the analyses presented in this manuscript.

For all tasks submitted either individually or as a group, students obtained timely feedback (within 1 week) and despite some tasks being formative, there were defined deadlines for submission. The assessment tasks were marked by 12 demonstrators who facilitated the learning of the students in the practical classes and workshops. All demonstrators had an education level of at least an undergraduate Bachelor's degree, with each demonstrator given a detailed marking rubric and correct responses, to ensure similar standards for all demonstrators. All demonstrators undertook training to ensure consistency in comprehension, and teaching standards across the groups. In addition, approximately 20% of the assignments were remarked by independent persons associated with the subject. Typically demonstrators marked between 11 and 26 scientific manuscript assignments. For the scientific communication assignment there was no significant difference in the average marks across the different demonstrators. Demonstrators were not aware of the prior level of achievement of the students.

All marks are expressed as a percentage of the maximum mark for each component, with 100 being the maximum mark. The independent measures consisted of the number of formative drafts submitted by the student as well as the marks obtained by the students for 1) their average prior level of achievement from subjects completed prior to Research Based Physiology, 2) the students' mark for the scientific manuscript assignment, 3) the students' average mark for all assessment testing theoretical content in Research Based-Physiology overall and finally 4) the students' average mark for all experimental design content in Research Based Physiology overall.

Statistics

All statistical analyses were conducted using SPSS. All data is reported as mean ± SEM, to indicate the variability of the data. Statistical significance was accepted at $p < 0.05$. Kendall's rank coefficients were calculated between two variables (drafts vs assignment; drafts vs prior level of achievement; prior level of achievement and assignment; prior level of achievement and theoretical content; prior level of achievement and experimental design) within each achievement level. Repeated measures ANOVA with the Bonferroni adjustment for multiple comparisons was used to compare marks (prior level of achievement, assignment, theoretical content and experimental design) within each achievement level. One way ANOVA with a Bonferroni post-hoc test was used to compare the number of drafts between the different achievement levels.

Results

A number of findings were identified from our analysis. Firstly overall, there was a significant difference in the number of drafts submitted by the different groups, so that high-achiever students submitted the greatest number of drafts and the low-achiever students submitted the least number of drafts (Figure 2).

Figure 2

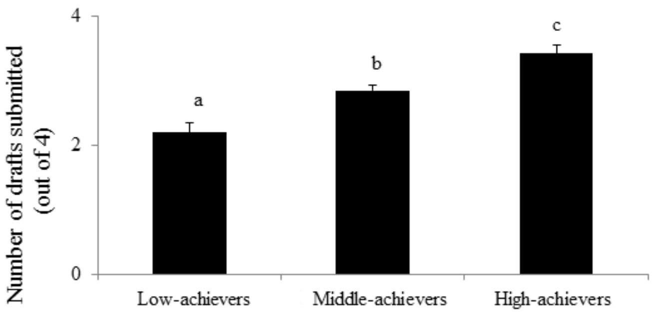

Figure 2. Average number of drafts submitted from students enrolled in Research Based Physiology in 2013, grouped according to their prior level of achievement. The maximum number of voluntary drafts is 4. Significant differences ($p<0.05$, one-way ANOVA, with a Bonferroni post-hoc test) between the achiever groups are indicated by lower case letters that differ (a, b, c); for example "a" is different from "b" and "c". Data are represented as means ± standard error of the mean (n = 55-188).

Within each achievement level, there was no significant Kendall's rank coefficient with the students' prior level of achievement and the number of formative drafts submitted (Table 1). Low and middle-achievers, but not high-achievers, had a significant Kendall's rank coefficient between the number of drafts they submitted and their final assignment grade (Table 1).

Table 1

Correlation Co-efficient (r) separated into prior level of achievement (n = 332)

	Number of drafts vs Assignment mark	Number of drafts vs Prior Level of Achievement
Low-achiever (n = 89)	0.218*	0.084
Middle-achiever (n = 188)	0.212*	0.108
High-achiever (n = 55)	0.096	0.211

Note. P* <0.05

Secondly, only low- and middle-achiever students had a significant Kendall's rank coefficient between their scientific manuscript assignment mark and their average prior level of achievement, with no significant Kendall's rank coefficient observed in high-achiever students (Table 2).

Table 2

Correlation Co-efficient (r) between prior level of achievement and assignment, theoretical content and experimental design marks (n = 332)

	Assignment marks	Theoretical Content marks	Experimental Design marks
Low-achiever (n=89)	0.166*	0.119	0.064
Middle-achiever (n=188)	0.17*	0.118*	0.129*
High-achiever (n=55)	0.126	0.173	0.072

Note. P* <0.05

Thirdly, a significant Kendall's rank coefficient was obtained for the middle-achievers' for the theoretical content and experimental design marks compared to their prior level of achievement (Table 2). No significant Kendall's rank coefficient was obtained for the comparison between the theoretical content and experimental design marks, and the prior level of achievement for low- and high-achievers (Table 2).

Finally, within group comparisons demonstrated that, for all groups, there was a significant increase in their assignment mark compared to their prior level of achievement (Figure 3). Further, there was a significant improvement from their average prior level of achievement compared to both the theoretical content and experimental design mark, for the low- and middle-achievers. High-achievers showed an improvement in their experimental design mark, but no difference in their theoretical content mark for Research Based Physiology compared to their prior level of achievement (Figure 3).

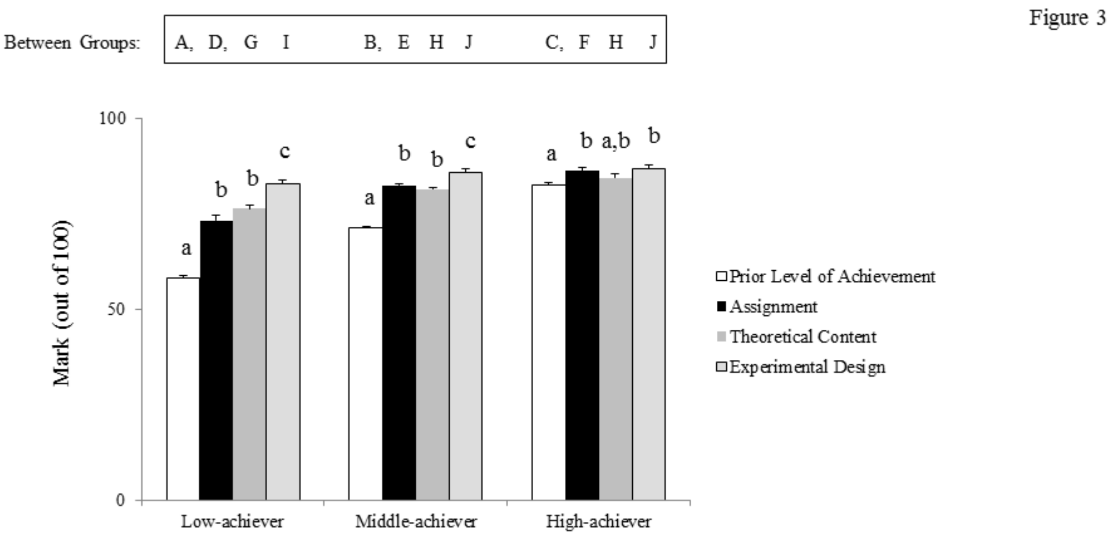

Figure 3. Breakdown of marks from students enrolled in Research Based Physiology in 2013, divided into prior achievement status. The average marks (out of 100) for the students enrolled in Research Based Physiology for their average prior level of achievement, assignment mark, mark from theoretical content in the subject as a whole and mark from experimental design components in the subject as a whole. Significant differences (p<0.05,

repeated measures with the Bonferroni adjustment for multiple comparisons) within the achiever groups are indicated by lower case letters that differ (a, b, c); for example "a" is different from "b" and "c", but "a,b" is not different from "a" or "b". For each mark, significant differences ($p<0.05$, one-way ANOVA, with a Bonerroni post-hoc test) between the achiever groups are indicated by upper case letters that differ (A, B, C, etc); for example "A" is different from "B". Data are represented as means ± standard error of the mean (n = 55-188).

Between the different groups, the assignment marks, theoretical content and experimental design marks for middle achievers were significantly higher than those of the low achievers, with high-achievers receiving a higher assignment mark then both low- and middle-achievers (Figure 3). However, there was no difference between the middle- and high-achievers for their theoretical and experimental design marks (Figure 3).

Discussion

We describe the use of a scaffolded learning approach, with active-learning lectures, small-group discussions and collaborative workshops, to teach basic science students' experimental design and scientific communication skills modelled on a scientific manuscript. The comparison of students' prior average mark, and their scientific manuscript assignment mark supports the hypothesis that this scaffolded learning approach improved their scientific literacy by writing of a scientific manuscript assignment, irrespective of students' prior achievement.

The approach employed utilised a variety of techniques to develop the understanding of a number of key topics including the basics of experimental design, theoretical knowledge and scientific communication. Variability in formats ensured students' learning styles were all catered for irrespective of their achievement level and that this approach provided students with an opportunity to develop their skills through initial modelling of best practice, followed by feedback on their own work. Students were given opportunities to develop their writing skills through lectures which explicitly described the key aspects of the different sections of the manuscript, as well as formative drafts. The high-achievers submitted a significantly higher number of drafts compared with low- and middle-achievers (Figure 2), which may be the result of the high-achievers preferring written assessment tasks (Rivard, 2004). However, the number of drafts high-achievers submitted did not correlate with their assignment mark or prior level of achievement (Table 1). Anecdotally, students' noted that a scientific manuscript assessment task was novel, and as this task is not simply based on rote learning, high-achievers may have found it to be a challenge.

With the adoption of the scaffolded learning approach, in all groups, there was a significant increase between students' average prior level of achievement and their assignment mark (Figure 3). Between the different groups, the assignment mark was significantly higher for the high-achievers, compared to the low- and middle-achievers, which suggests that despite the improvement in the assignment marks, that the students "ranking" within their overall student co-hort is unaltered by the scaffolded learning approach. This could possibly be due to some students' lack of engagement with the learning tasks, as evident by the lower number of drafts submitted by the low- and middle-achievers (Figure 2). Of interest, middle-achievers obtained the same marks for the theoretical content and experimental design as the high-achievers (Figure 3). Theoretical content and experimental design where largely taught in interactive lectures, group workshops and traditional practical classes. Thus, this scaffolded learning environment may have favoured middle-achiever students. Anecdotally, students actively engaged in group discussion workshops, and students indicated that this mode of instruction allowed them to develop their ideas and knowledge. Future studies should clarify the preferred mode of teaching for this cohort.

Importantly, there was no correlation between the number of drafts and the students' average prior achievement (Table 1). However, there was a significant correlation between the number of drafts submitted and students' assignment mark in low- and middle-achiever groups (Table 1). Thus, for low- and middle-achievers there was benefit in submitting more drafts, as it increased their assignment mark. These findings are not surprising, further reinforcing evidence of previous long held beliefs about student engagement and its effect on academic performance. Thus, students that are engaged with the task and submit more drafts may have an improvement in their written scientific communication skills. For middle-achievers, their assignment, theoretical content and experimental design marks all correlated with their prior level of achievement. While for low-achievers only the assignment mark correlated with their prior level of achievement (Table 2). Thus, the scaffolded learning approach adopted in Research Based Physiology best supported middle-achievers in this cohort.

In general students enjoyed Research Based Physiology, and saw benefits of its structure and design. From the student experience survey:
"The thermoregulation prac was good fun. Planning it, running it and also despite being stressful the write up was actually kind of fun too. I also really loved that we had a prac every week that related to the lecture content taught. I thought it was a fantastic way to introduce topics to us. "
Despite engaging with the subject, others used the content in Research Based Physiology to identify future areas of interest that would not be of consideration for their careers. From the student experience survey:
"The best aspect of this subject is getting to learn a little bit about what the world of research is like, as that is somewhere I want to go to (though not in this field)."

Writing scientific literature which encompasses high order critical thinking, science comprehension and communication is often a challenge for students (Drury and Muir, 2014). As previously described, an important characteristic of the Research Based Physiology subject was that tasks were interdependent with concepts associated with the scientific manuscript task, comprised of organised networks of related information. This structure is thought to enable students to better understand the task itself (Glynn and Muth, 1994) In the current study we have specifically developed a whole subject approach that enhances scientific communication through a scaffolded approach which uses best-practice models, peer discussion and assessment tasks that are linked. Certainly, there is an emerging ideology that the best methods to accommodate student differences are based on a variety of formats, with teaching approaches informed by research (Rivard, 2004). Importantly, to allow students to maximise such a strategy it is critical that there is clarity in the learning sequences, as well as a clear description of the "pathway" that will be followed to achieve a successful outcome. In line with this, assessment tools need to produce ongoing, reliable records of learning. Further, continuous assessment allows for ongoing feedback which students can use to develop their skills. From the student experience survey:
"The continuous assessment throughout semester helped me get a better idea of how I was going in the subject."

An essential component of this subject was the group discussion tasks. Previous work has suggested that the use of peer discussion can enhance scientific learning (Rivard, 2004). Group discussion tasks in Research Based Physiology did have an assessment component. However, these were based on a single submission by the group. Therefore, for this analysis and discussion of the subject as a whole, group assessment tasks and their associated marks were not included in the discussion of this manuscript. Group membership was assigned by surname and the particular class (students were allocated to 5 different practical classes), so that there was heterogeneity in the groups based on average prior level of achievement. Of importance to this, a previous study has demonstrated that group heterogeneity is not a determinant factor in the efficacy of students' learning (Cheng et al, 2008).

A number of limitations exist in this study. Firstly, within this study design there is not a true "control". That is a cohort of students who undertook the scientific communication task, without the scaffolded learning approach which included direct instruction, group-discussion as well as formative feedback. Notwithstanding this, variability did exist between the groups, suggesting that the major findings were not confounded by this lack of control group. Secondly, we did not assess the prior level of experience in writing a scientific manuscript assessment task. We assumed that an increase in their scientific manuscript task compared to their average prior level of achievement was an indication of an improvement in their written scientific skills. Certainly based on anecdotal evidence, a number of students independently had described how during their degree program thus far there were no similar assessment tasks and certainly no task where the content closely mirrored the assessment components in the same manner. All students enrolled in Research Based Physiology have 2 semesters of a first year Biology subject and 1 semester of a first year quantitative science subject (chemistry, physics, maths, or psychology) as a pre-requisite. However, there are a varied number of other prior learning subjects that students have completed. Therefore, students may have been exposed to a broad range of prior subjects which may have enhanced understanding of the principal task. Thirdly, students' prior exposure to the theoretical content in a lecture based Human Physiology subject may have occurred previously, or concurrently. Because the two subjects do not have a mirroring of content, students who previously completed the full semester of Human Physiology may have a broader background theoretical knowledge, compared to students undertaking the subjects concurrently. However, the nature of the assessment tasks in Research Based Physiology and the content was such that there is likely to be little benefit from completing the Human Physiology subject prior to Research Based Physiology. Finally, the subject, in its current form, can be a challenge, as the recruitment of knowledgeable and adequately trained demonstrators can be a limitation, especially in some educational University environments. Fortunately this is not an issue at our University, but must be taken into consideration when adopting such a learning approach. However aspects of this subject could be adopted to enhance the learning outcomes of the student group, and provide diverse education for students with differences in their prior level of achievements.

In summary, this study describes a scaffolded learning approach to enhance experimental design and scientific communication skills in a Bachelor of Science cohort. The use of active-learning lectures, small group discussion and formative feedback helped to develop scientific literacy skills in the student cohort. A significant improvement between their average prior level of achievement and assignment mark was noted in all students irrespective of their average levels of achievement. Therefore, utilising multiple modes of teaching provided benefits to students across all prior achievement levels. The scaffolded learning approach, either in its entirety or individual components, would be adaptable to scientific subjects across a number of disciplines. Future studies should determine if these skills are retained in subsequent undergraduate years.

References

Australian Learning and Teaching Council (ALTC) (2011). Learning and teaching academic standards project Science. Retrieved June 26, 2015, from http://www.olt.gov.au/resource-library.

Australian Government Department of Education, Employment and Workplace Relations (DEEWR) (2011). Assessment of generic skills discussion paper 2011. Retrieved June 26, 2015, from http://www.innovation.gov.au/highereducation/Policy/Documents/AssessGenericSkills_Finaldiscussionpaper.pdf.

Brownwell, S.E., Price, J.V., & Steinman, L. (2013). A writing-intensive course improves biology undergraduates' perception and confidence of their abilities to read scientific literature and communicate science. *Advances in Physiological Education, 37* (1), 70-79.

Cheng, R.W.-Y., Lam, S.-F., & Chan, J.C.-Y. (2008). When high-achievers and low achievers work in the same group: The roles of group heterogeneity and process in project-based learning. *British Journal of Educational Psychology, 78* (2), 205-221.

Cuban, L. (1989). The "at-risk" label and the problem of urban school reform. *Phi Delta Kappan*, *70* (10), 780-801.

Drury, H & Muir, M. (2014). Using an E-Learning Environment for Developing Science Students' Written Communication: The Case of Writing Laboratory Reports in Physiology. *International Journal of Innovation in Science and Mathematics Education*, 22, 79-93.

Gillen, C.M. (2006). Criticism and interpretation: teaching the persuasive aspects of research articles. *CBE Life Science Education, 5* (1), 34–38.

Glatthorn, A.A. (1991). Restructing schools: curriculum reform. In K.M. Kershner & J.A. Connolly (Eds), *At-risk students and school restructuring* (pp 77-84). Philadephia, PA: Research for better schools.

Glynn, S.M., & Muth, K.D. (1994). Reading and writing to learn science: achieving scientific literacy. *Journal of Research in Science Teaching, 31* (9), 1057-1073.

Graduate Careers Australia (2013). Graduate Outlook Survey 2013. Retrieved June 26, 2015, from http://www.graduatecareers.com.au/research/surveys/graduateoutlooksurvey/.

Howitt, S.M., & Wilson, A.N. (2014). Revisiting "Is the scientific paper a fraud"? *EMBO Reports, 15* (5), 481-484.

Kardash, C.M. (2000). Evaluation of an undergraduate research experience: perceptions of undergraduate interns and their faculty mentors. *Journal of Educational Psychology, 92* (1), 191–201.

Lehr, J.B., & Harris, H.W. (1988). At risk, low achieving students in the classroom. Washington DC: National Education Association.

Moni R.W., Hryciw D.H., Poronnik P., & Moni K.B. (2007) Using explicit teaching to improve how bioscience students write to the lay public. *Advances in Physiological Education, 31*, 167-75.

Mulnix, A.B. (2003). Investigations of protein structure and function using the scientific literature: an assignment for an undergraduate cell physiology course. *Cell Biology Education, 2* (4), 248–255.

National Research Council. (2003). *BIO2010: Transforming Undergraduate Education for Future Research Biologists.* Washington, DC: National Academy of Sciences Press.

Pechenik, J. (2004). A Short Guide to Writing about Biology, 5th Ed. New York: Harper Collins.

Porter, J.R. (2005) Information literacy in biology education: an example from an advanced cell biology course. *Cell Biology Education, 4* (4), 335–343.

Rivard, L.P. (2004) Are language-based activities in science effective for all students, including low achievers? *Science Education, 88* (3), 420-442.

Rivard, L.P., & Straw, S.B. (2000). The effect of talk and writing on learning science: An exploratory study. *Science Education, 84*, 566-593.

Smith, GR. (2001). Guided literature explorations. *Journal of College Science Teaching, 30* (7), 465–469.

Thornburg, DG. (1991). Strategy instruction for academically at-risk students: An exploratory study of teaching "higher-order" reading and writing in the social studies. *Reading, Writing and Learning Disabilities, 7* (4), 377-406.

Tonissen, K.F., Lee S.E., Woods, K.J. & Osborne, S.A. (2014). Development of Scientific Writing Skills Through Activities Embedded into Biochemistry and Molecular Biology Laboratory Courses. *International Journal of Innovation in Science and Mathematics Education*, 22(4), 1-14