AUTHENTIC LEARNING EXPERIENCES IN A THEORY HEAVY LEARNING CONTEXT

Jurgen Schulte[a], Neela Griffiths[b]

Presenting Authors: Jurgen Schulte (Jurgen.Schulte@uts.edu.au), Neela Griffiths (Neela.Griffiths@uts.edu.au)
[a]SciMERIT, School of Mathematics and Physical Sciences, University of Technology Sydney, Australia
[b]Academic Language & Learning, IML, Office of the DVC (Education & Students), University of Technology Sydney, Australia

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ABSTRACT

Assessment in an undergraduate physics subject was re-designed to challenge and inspire students to develop and apply their disciplinary and non-disciplinary skills in a practice-based, authentic assignment task. The aims of the re-design were to expose students to workplace practice and increase their engagement in the subject. Traditionally, as a response to its emphasis on disciplinary theory, science is largely assessed by way of content-focussed class tests and examinations, activities not reflected in workplace practice. These summative assessment types measure student attainment of knowledge rather than enable deeper understanding and learning. However, introducing students to 'real-world' practice-oriented assessment tasks can enhance student engagement and promote learning. To achieve these aims the assignment was carefully scaffolded to give students the opportunity to improve their scientific writing skills, develop an approach to systematic research, build a greater understanding of the peer-review process and acquire skills in self and team management. The task required students to work in groups to research and write a research paper based on a meta-study model. Their papers were then compiled and published in a student peer-reviewed research journal. The impact of this intervention has been evaluated over three years through focus groups with the majority of the students commenting positively on their learning and engagement in the subject. This reflective article discusses the effectiveness of the assignment design, its scaffolding, the peer-review process and the authenticity of the workplace-setting. Suggestions are made as to how to further improve this type of assignment design. This workplace-focused intervention may be of interest to educators in other disciplines.

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INTRODUCTION

Although science graduates need to communicate effectively with non-scientists once they enter the workplace, little if any training in communication and professional skills is covered in traditionally content driven physics subjects. Typically physics is assessed summatively by way of content-focussed class tests and a final theory exam, with little lecturer-student interaction, and even less student-to-student interaction. The subject Energy Science and Technology (68412) is one example of a subject that has been taught in this conventional way. It is a one-semester, second year compulsory subject for physics majors (20 - 40 students per term) which covers the thermodynamics of macroscopic and microscopic processes in the context of energy conversion, energy saving and related applications. It introduces students to disciplinary theory and prepares the theoretical scaffolds for subsequent subjects. This focus leaves little room for linking theory to realistic practical applications or covering more than one aspect of theory in student experiments and even less room for the integration of non-disciplinary skills.

Research conducted in Australia (Rodrigues, Tytler, Darby, Hubber, Symington & Edwards, 2007) into the usefulness of a science degree as a foundation for employment finds that science graduates feel that they have been underprepared for the skills they require in the workplace. Based on these findings, Rodrigues et al. recommend that there should be opportunities in the degree programs 'for students to practise and receive feedback on these skills' (2007; p. 1431). This recommendation is reflected in the push to integrate Graduate Attributes (GAs) into Australian university policy nationwide. The Faculty of Science at the University of Technology Sydney (UTS) has a number of work-ready oriented GAs including Communication Skills, Professional Skills and Life-long Learning. Aligning these non-disciplinary knowledge GAs with the theoretical content of the subject Energy Science and Technology posed some challenges. To meet the GAs outlined in the subject learning outcomes, we introduced a workplace experience simulation based on practical applications of the theoretical material covered in the lectures. This reflective article discusses the effectiveness of the intervention's assignment design and the outcomes of integrating the work-ready oriented GAs.

To provide a more engaging and practice oriented, authentic learning experience, this new group-based, student peer-reviewed assignment replaces a class test and the final theory exam (which together accounted for 75% of assessment) and is designed to enable rather than simply measure learning (Maclellan 2004; p. 27). It allows this theoretical subject to become a practical, student self-managed learning experience through its application and assessment of the targeted GAs *Disciplinary Knowledge*, *Enquiry and Innovation* in addition to embedding the *Communication* and *Professional Skills* which prepare students for their workplace.

The student peer-reviewed research paper was introduced to enable students to investigate specific applications of theory covered in lectures and to apply and reflect on, in stages, their acquired *Disciplinary Knowledge*, and to experience and better understand the scientific writing process. In the peer-review process student engagement is enhanced when a link is forged between peer feedback and professional behaviour (Ladyshewsky 2013; p. 174). Another advantage of peer feedback in the review process is that students are more likely to reveal their lack of knowledge to other students (Ladyshewsky 2013; p. 176), which may lead to improved learning and engagement. The task required students to utilise their writing skills in a discipline specific way, in itself a move away from the more traditional, and generic, 'add-on' approach to developing 'study skills' external to a subject (Wingate 2006). The writing component of the task was also fundamental; findings have shown 'that in higher education writing is essential for the understanding and construction of subject-based knowledge' (Berkenkotter & Huckin 1995, cited in Wingate 2006; p. 461). In this context, it was also important that while the lectures covered the theoretical, thermodynamics-related background of thermodynamic engines, the group assignment supported student learning about state-of-the-art research and practical realisations of power generation.

To provide an attainable pathway into research conducted in a professional environment students were instructed to go beyond a literature review of their topic and to adopt a meta-study approach. In this approach, results from different data in the group's research texts are synthesised in a systematic way to identify data patterns that are not apparent in any of those sources in order to create new knowledge (Greenland & O'Rourke 2008). Another objective was that the group work exposed students to the practice of working in a team and managing a pre-set goal, team dynamics and team tasks. The writing of an academic research paper for publication in a research journal requires students to meet specific style guidelines and a submission deadline and participate in a rigorous peer-view process. In the first iteration their research papers were then collated for professional publication in an internal student research journal. Since 2015 they have been professionally published in an open source journal published by UTS ePRESS (c.f. Schulte 2016).

THE ASSIGNMENT - THE STUDENT RESEARCH PAPER PROJECT

The first step of the assessment task is for the students to choose the topic of their research paper project from a range of power generation systems or to propose a different system they are interested in. The idea behind this open project theme approach is that students would find it a more enjoyable learning experience if they study a project that they are really interested in, instead of aligning with one covered in the lecture (coal fired power plants, for instance). Surprisingly, over the course of this study over 80% of students have selected research topics that are not taught in any subject in the School of Mathematical and Physical Sciences. Another benefit of allowing each student to choose their project theme is that many conceptually different practical applications of theory could potentially be covered in depth at the same time. While the original intention was for students to self-select their own groups, the lecturer agreed to allocate them to groups depending on their topic choices.

The compilation of the research journal provided students with practical learning experience in applying scientific methods to produce a meta-study research paper. The use of a meta-study format allowed the students to conduct some real scientific work at this very early stage in the undergraduate course. While students have some familiarity with literature reviews, their capacity to conduct scientific research at the level presented in current high-level research journals is very limited at this stage. A meta-study allows students to apply their current knowledge, read high-level research journal articles and extract some data from the articles that are common to their project theme and are relevant to the syllabus. The key focus of the meta-study here is to compare data from the various original sources, highlight the relationships and commonalities in the sources, identify gaps in knowledge, and synthesise new insights without necessarily being an expert in the subject area.

The assignment has been designed to create an environment replicating the scientific publication process:

- gaining expertise in an unknown topic within a short period of time;
- consulting scientific databases, reading scientific papers and extracting relevant information;
- formulating a research objective for the meta-study;
- writing a paper in a prescribed scientific publication format;
- working in a research team with a range of expertise and managing workloads within a team;
- peer-reviewing and assessing other papers according to prescribed peer-review guidelines;
- completing and submitting the meta-study paper within the journal's publication timeline.

The assignment was scheduled such that after completion of several rounds of peer-review (feedback cycles) sufficient time was left for final papers to be collated to produce a professionally produced peer-reviewed student research journal with sufficient issues printed to allow for copies for each student in class as well as distribution across the faculty.

SCAFFOLDING

Scientific writing

Students enter university with a background in structured writing as it is embedded in the high school English and Science curricula in the form of essays and formal reports. Written scientific research communication builds on these skills, while also following writing conventions that are discipline specific. To give students clear guidance as to what is required in the assignment, we provide an online materials bank. This includes a pre-formatted paper template (commonly provided by journals as well as conferences) and a research paper style guide. In addition, selected literature about practical scientific writing is provided. Often, in writing exercises such as this one, students are overwhelmed and have difficulty judging the breadth and depth of what is required of their work (Wingate 2006). A detailed, graded rubric has been developed for each of the targeted GAs to help students to scaffold their own writing as they progress through their research and peer-review feedback cycles.

Peer-review

At this stage in our undergraduate program, students have only limited experience with peer-review, and no experience with the formal peer-review process. In order to implement a peer-review process, the online tool SPARK^{PLUS} is used (Willey & Gardner 2008). SPARK^{PLUS} allows us to implement a scaffolded peer-review learning experience that includes self-assessment. In the context of the research journal, peer-review is seen as a three-fold learning experience. Students work on their papers in small groups of 3-5 students. They then submit their draft papers for peer-review using a set of peer-review rubrics and the online peer-review tool for recording their assessments (Table 1).

The final paper must be submitted on the pre-set journal date deadline after a final peer-review. The written peer-review feedback requires a minimum number of words for each feedback criteria and has to be completed within one week of submission. After receiving their group paper and in-group performance feedback, students have two weeks to work on their second draft. This is submitted and they again have one week to complete the peer-review process. At this point, group papers are at an advanced stage and students have become familiar with the rigor and consequences of the peer-review process. After this second round of the peer-review process students have another two weeks to prepare for their final submission and final peer-review. Throughout the peer-review process, groups have regular one-on-one feedback sessions with the lecturer to resolve questions about the paper writing, discipline content as well as group specific issues.

SPARK^{PLUS} allows students to review each group member's contribution to their own group work in terms of an overall contribution, contribution to efficient functioning of the group, leadership and the writing process. Students can also self-assess their personal performance within their groups. Self-assessment is an integral part of learning and a key capability of a confident professional. It is a powerful tool, which 'directly enlists the student's motivation for learning and relates the outcomes of the learning enterprise to the initial reasons for beginning it' (Justice & Marienau 1988; p.50), and it is 'a key foundation to a career as a lifelong learner' (Boud 1995; p.14).

Table 1: Scaffolding of peer-review and feedback.

Week 1 (Online Material)	research paper style guide pre-formatted paper template meta-study example paper practical scientific writing guide graded rubric of expectations	f
Week 6 (1st Draft Paper)	peer students' written feedback lecturer written feedback	f
Week 7	lecturer 1-on-1 group feedback	f
Week 9 (2nd Draft Paper)	peer students' written feedback lecturer written feedback	f
Week 10	lecturer 1-on-1 group feedback	f
Week 12 (Final Paper)	peer students' written feedback lecturer written feedback	s
Week 13 (post-Journal)	journal distribution lecturer feedback	f

f: formative s: summative

EVALUATION

Student Experience
As part of the evaluation of the re-design of the assessment, students have been invited to participate in focus groups (ethics approval UTS HREC Ref. No. 201400358), which are conducted in two stages. Students individually respond to a set of open-answer questions and then participate in a discussion facilitated by colleagues who do not teach in the subject. The following student comments were derived from these written and recorded sources.

Over the three iterations of the subject, of the 82 students, 55% have participated in the focus groups. Overall, they have had positive comments to make about this novel assignment task, indicating that the research paper journal project has enhanced their learning experience in the subject. They have commented particularly on how it supported their understanding of their topic content and how to conduct a meta-study and write a scientific paper. As one student pointed out, 'there are ways to pass tests without understanding but this way we have to understand'. Others commented that the drafting process made it easier for them to retain information rather than when they cram for exams. One student 'enjoyed the self-managed learning the most, as I feel information I've collected during this project will have greater "staying power" than it may otherwise'. Several also stated that the fact that the journal would be an internal publication motivated them to put in the effort required.

The majority of the respondents have commented positively on their learning in relation to team work skills, time management, self-directed learning, scientific writing and communication skills and could see the application of this learning in the workplace.

Workplace scenario
In response to the focus group question as to why they have been set the assignment more than two thirds referred to the 'real world' experience, the opportunity to work in groups and to learn from each other to 'achieve a common goal'. Also, they have been 'introduced to the world of scientific writing' and doing research. One student noted that it made 'the subject more applicable to future careers' and 'hands-on'. Some of the students (40%) have identified the value of learning to work in teams with responses including 'I have also learned a lot about being a leader and making sure everyone is on the right track, but in a positive and encouraging manner' and '[W]orking in a team was rewarding, it helped to improve my skills of collaboration and collaborative time management.' However, one student admitted that a drawback was 'ensuring everyone is on the same page'.

Peer-review feedback cycles
There have been mixed reactions to the peer-review experience with some students finding it very helpful while others have found it a burden. Almost half of the students (47%) commented that they needed more training in how to be peer-reviewers and recommended a more scaffolded process. In general, they seemed to understand that the peer-review process was intended to engage them in a simulation of professional practice although one student revealed that 'I wasn't actually aware that scientific papers were reviewed in this way before publishing.' It was evident that a number of them found the peer-review process quite challenging.

Value of the peer-review feedback
Students reported (58%) that they found the lecturer's feedback to be the most helpful especially as some felt that they did not have the expertise to give valuable feedback. One commented that 'it was good to see feedback from class-mates too, as they often had different perspectives on the paper writing process.' Another commented that 'I got more out of giving feedback than I received.'

Engagement
Student engagement in the new task has been particularly evident in their responses to what they liked about it. Again, almost half of the respondents (47%) explicitly commented positively about being able to choose their own topic; one described it as 'fantastic' and another as 'inspiring'. Some said (18%) it motivated them to read and learn about the topic. They liked (47%) choosing their own topic as it gave them ownership of the assessment task as they were 'not doing what we have been told to do' but had the 'freedom of choosing'.

One student, who thought the task was designed to provide the students with exposure to academic writing, stated '[T]his type of task is not one I am familiar with. I really enjoyed it and would enjoy doing it again.' Another student identified the transferability of the skills 'The self-managed learning was a good way to see what I would have done differently for another project in terms of time management and working within a team.'

Lecturer's Experience
The subject was re-designed and is taught by the lead author, a highly experienced physics lecturer. Providing a hands-on practice-based learning experience for students, enabling a high degree of ownership of learning and opportunities for reflection, required a considerable investment of time. It has been most rewarding to see students engaged in cycles of learning and improving their disciplinary knowledge, professional and communication skills. The evaluation shows that the assessment re-design has encouraged the application and retention of knowledge and skills rather than rote learning for a final exam. The multiple cycles of peer-review and feedback (Table 1) although quite time consuming for the lecturer and students, are balanced by the fact that there is only one class test and no final exam to prepare or mark. In our opinion, it is more interesting and rewarding to assess student work when there is a chance to see it improving than assessing an examination when there is little or no opportunity for a cycle of feedback and learning after the final result. Since 2014, the pass rate of this subject has been 92±3% with an average mark of 66±3 which is similar to previous years although more skills are taught and assessed.

The new subject assessment has proven to resonate well with students, both in terms of learning experience and self-management. Nevertheless, there have been occasions when we observed that some of our well intended initial planning failed to address its aims and therefore needed to be fine-tuned.

- We assumed that second year students would be prepared to form small informal groups of common interest especially as they were encouraged to choose their own project theme. In reality, the students are reluctant to do this. So, the lecturer creates groups based on the chosen project theme.

- Despite the provision of an online bank of guidelines and scaffolding materials, students found it difficult to get started. Linking all constraints (timelines, team management, work format) and the academic work required (literature search, synthesising information, scientific writing) with the peer-review process was a major challenge for them especially in the first four weeks. As result, more

scaffolding and guidance has been provided. In 2016, specific workshops on literature searching, referencing and professional scientific writing for publication were timetabled into the subject.

- Although students are aware of the concept of peer-review in general terms, they have had no experience with the rigor of a formal peer-review in an academic context. It was thought that providing a well-structured assessment rubric for the peer-review process and allowing students to experience a professional peer-review process would help ease the stress of the peer-review task. However, students sometimes confused peer-review (formative feedback) with peer assessment (summative judgment) and felt intimidated about writing comments on their peers' papers. More guidance has been implemented into the scaffolding process along with an exemplar peer-review process that demystifies the backroom aspects of the process.

CONCLUSION

Our intention was to re-design the subject assessment in order to provide a challenging and inspiring learning experience. In this assessment re-design, students experience an aspect of the workplace of an academic beyond the lecturer's visible role as a teacher. We have introduced this re-design in a subject with a traditionally heavy theoretical content which in science would normally be assessed through examination, an activity that is not found in a workplace. The success of the intervention is evident from the pass rate and the average mark which has not changed compared to previous years although more communication and professional skills are taught and assessed. It is pleasing to see how students produce new knowledge from the secondary research into a meta-study. They are clearly motivated by the challenge of a meaningful task that has a tangible outcome, a peer-reviewed student research journal. Thus, using the basic premise of a meta-study creates an environment for students that allows them to experience the 'real thing'. As one student commented 'It's pretty cool to have a published paper.' They are also engaged in self-study and applying the theoretical content learned in the lectures, in a scenario that supports a better learning experience than do summative examinations.

We believe the general framework of a group-based, meta-study approach with a peer-review process at undergraduate level may be easily transferrable to other content driven science courses as well as other research-intensive disciplines. However, there are questions related to its scalability and peer-review intensive mode of delivery.

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