PUTTING THE PROFESSIONAL INTO PRACTICE-BASED LEARNING

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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 assignment task. The aims of the re-design were to expose students to workplace practice and increase their engagement in the subject. 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 was evaluated through a focus group discussion with the majority of the students commenting positively on their learning and engagement in the subject. The effectiveness of the assignment design, its scaffolding, the peer-review process and the authenticity of the workplace-setting are discussed. 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 STEM disciplines.

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INTRODUCTION

Workplace ready science students should be able to communicate effectively with non-scientists; however, physics subjects that are taught in a traditional way are heavily content dependent with very little attention being paid to the communication and professional skills required for employability beyond disciplinary knowledge. Typically physics is assessed summatively by way of content focused class tests and a final 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 core subject in the physics degree which covers the thermodynamics of macroscopic and microscopic processes in the context of energy conversion, energy saving and related applications. It introduces students to a large amount of 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 practice and receive feedback on these skills' (2007, p. 1431). This recommendation is reflected in the integration of graduate attributes (GAs) into university policy nationwide. The Faculty of Science at UTS has a number of work ready oriented GAs including Communication Skills, Professional Skills and Life-long Learning. However the theoretical nature of the subject Energy Science and Technology posed some challenges when it comes to alignment with the non-disciplinary knowledge related graduate attributes (GA). Therefore, an intervention required a workplace experience simulation based on practical applications of the theoretical material covered in the lectures.

To provide a more engaging and practice oriented learning experience, the compilation of a student peer-reviewed research paper journal was introduced as a new assessment. This new group-based, student peer-reviewed assignment replaces a class test and the final exam (which together accounted for 75% of assessment) and is designed to enable rather than simply measure learning (Maclellan,

2004). It allows this predominantly theoretical subject to become a practical, student self-managed learning experience that is stimulating and challenging and helps to facilitate desired graduate outcomes that prepare students for their future workplace.

The student peer-reviewed research paper was introduced to enable students to investigate specific applications of theory covered in lectures to allow more room for students to engage with the subject content; and to foster Enquiry, Innovation, Professional, Communication and Life-long Learning skills (the targeted GAs). This peer-review process enabled students to apply and reflect on, in stages, their acquired Disciplinary Knowledge (one of the GAs) 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). 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), which may lead to improved learning and engagement. The authentic 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 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. To further foster student engagement, an authentic professional workplace activity has been chosen as a backdrop for their self-study work. 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. At the end of the peer-review process, the research papers were collated for professional printing, and published in an internal student research journal.

THE ASSIGNMENT - THE STUDENT RESEARCH PAPER PROJECT

The first step of the assessment task was 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 were interested in. The idea behind this open project theme approach is that students will 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). Figure 1 shows the project themes that the students selected. Surprisingly, the majority of students (81%) selected nuclear physics related projects (fusion/nuclear power), a topic area that is not taught in any subject in this school and was not seen as one that students would be interested in. Another benefit of allowing each group 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.

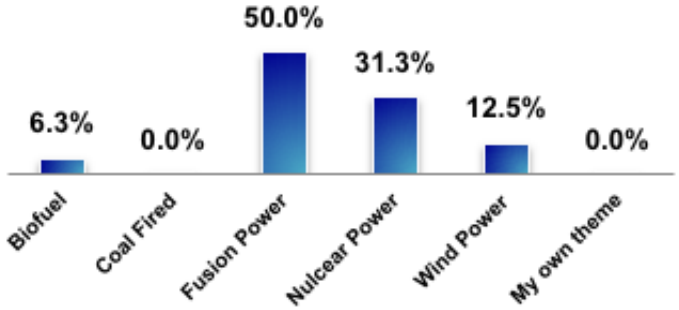

Figure 1: Students' selection of project themes

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 if not impossible 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 (in this case temperature, pressure efficiency and other thermodynamic parameters). 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 and synthesize new insights without necessarily being an expert in the subject area.

The assignment has been designed to create an environment similar to the creation of a real scientific publication, including:

- gaining expertise in an unknown topic within a short period of time;
- consulting scientific databases;
- reading peer-reviewed 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;
- managing research and paper writing workloads within a team;
- acting as a peer-reviewer for other group papers;
- assessing 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 professional 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. Through this process it was envisaged that students experience some practical aspects of professional research work, including working in a team, having one's work subjected to peer-review, acting as a peer-reviewer, being actively engaged in the research and discipline specific scientific writing process, working towards a (journal) deadline and enjoying the reward of seeing the work published in a professionally produced journal before the end of the teaching period.

SCAFFOLDING

SCIENTIFIC WRITING

It is assumed that students enter university with an extensive background in structured writing as it is embedded in the high school English and Science curricula in the form of essays and formal reports and in some elements of the literature review process (see, for example, NSW Board of Studies, 2009). 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, we provided an online materials bank. This included a pre-formatted paper template (commonly provided by journals as well as conferences such as ACSME) and a research paper style guide. In addition, selected literature about practical scientific writing was 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. A detailed, graded rubric was developed for each of the targeted GAs to help students to scaffold their own writing as they progressed through their research and peer-review feedback cycles.

PEER-REVIEW

At this stage in their undergraduate program, students have only limited experience with peer-review, and no experience with the formal peer-review process. In order to implement a professional journal peer-review process, the online tool SPARK^{PLUS} was used (Willey & Gardner, 2008). SPARK^{PLUS} allowed us to implement a scaffolded peer-review learning experience that included self-assessment. In the context of the research journal, peer-review is seen as a three-fold learning experience. Students worked on their papers in small groups of 3-5 students. They then submitted 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). A final paper was submitted on our pre-set journal date deadline and a final peer-review was applied. The written peer-review feedback required a minimum number of words

for each feedback criteria and had to be completed within one week of submission. After receiving their group paper and in-group performance feedback, students had two weeks to work on their second draft. Students submitted their group papers a second time and again had 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 the second round of the peer-review process students had another two weeks to prepare for their final submission and final peer-review. Throughout the peer-review process, groups had 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 actual writing of the paper. Students also self-assess their own personal performance within their groups. This allows for the peer-review to share appreciation among all group members. 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 Bank)	• 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 were invited to participate in a focus group. Thirteen students (out of 17) attended the focus group session and overall had positive comments to make about the new assignment task indicating that it had enhanced their learning experience in the subject (Figure 2). This was mainly because they really needed to understand their topic content in order to conduct a meta-study and write the 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 students 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. However, although the students recognised and

understood the inclusion of these features into the assignment some were unaware that these skills are included in the Faculty of Science non-disciplinary Graduate Attributes.

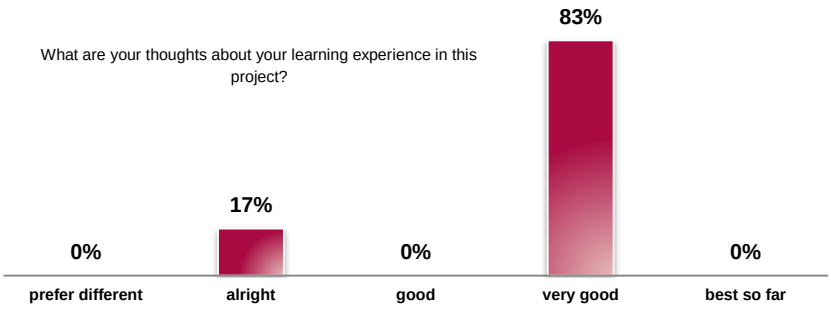

Figure 2. Students' rating of learning experience.

Workplace scenario
In response to the focus group question as to why they had 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 were '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'. Many of the students 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.' One admitted that a drawback was 'ensuring everyone is on the same page'.

Peer-review feedback cycles
There were mixed reactions to the peer-review experience with some students finding it very helpful while others found it a burden. Most agreed 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.' Evidently, a number of them found the peer-review process quite challenging.

Value of the peer-review feedback
Almost all the students 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 [cf. Willey & Gardner, 2010]. 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 was particularly evident in their responses to the prompt asking what they liked about it. Nearly three-quarters of the respondees commented positively about being able to choose their own topic; one described it as 'fantastic' and another as 'inspiring' and many said it motivated them to read and learn about the topic. A number mentioned indirectly that choosing their own topics 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.'

One 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 re-design of the subject assessment to give students a hands-on practice-based learning experience combined with a high degree of ownership of learning and ample opportunities for reflection on their learning and produced work required a considerable investment of time; as is

always the case when a subject is re-designed. It has been most rewarding to see students engaged in cycles of learning and improving their disciplinary knowledge, professional and communication skills. The assessment re-design encouraged the application and retention of knowledge and skills rather than accumulating them in a package to be discarded after a final exam without further reflection on their importance for their future study or professional lives. The multiple cycles of peer-review and feedback as shown in Table 1 appear to be quite time consuming but the fact that there was no second class test and no final exam to prepare as well as to mark balanced the workload out quite nicely. 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 chance for a cycle of feedback and learning after the final result.

The new subject assessment has proven to resonate well with students, both in terms of learning experience and self-management. Nevertheless, as the teaching weeks passed by there were occasions when we observed that some of our well intended planning failed to address its aims and therefore needs to be fine-tuned in future. Some possible reasons for the unintended outcomes are the following:

- *Forming groups* - It was assumed that by the second year students would be prepared to form small informal groups of common interest and that the group formation for the project work could be a student self-organised activity especially as they were encouraged to choose their own project theme. In reality, students felt reluctant to form groups and asked the lecturer to create groups around their chosen project theme. (See Figure 1 for student choices).
- *Providing guidance on the task* - It was thought that providing an online bank of supporting and scaffolding materials at the beginning of the semester would give students clear directions as to what was required as well as define the boundaries of the project work. However, it took much longer than anticipated for students to get their heads around the workplace related assignment requirements and the practical constraints. 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 especially during the first four weeks. Thus, more guidance with the unfamiliar peer-review process is required during this period.
- *Scaffolding peer-review* - Students were aware of the concept of peer-review in general terms, however, they had no experience with the rigor of a formal peer-review in an academic context. In addition, the use of the technology (SPARK^{PLUS}) was unknown to them. 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. Students sometimes confused peer-review (formative feedback) with peer assessment (summative judgment) and felt intimidated about writing comments on their peers' papers. Sometimes students were unsure how to formulate a peer-review response. More guidance is needed in that respect and could be implemented into the scaffolding process along with an exemplar peer-review activity that demystifies the backroom aspects of the peer-review.

CONCLUSION

Our intention was to re-design an assessment with the aim of 'putting the professional into practice-based learning' in order to provide a challenging and inspiring learning experience. From the experience we have gained and the student focus group responses it appears that this has been a worthwhile undertaking. The majority of graduates will find work outside the university and for that reason graduate attributes are informed by industry requirements. Most students have some idea about what work might be like in their future work environment; however, this may be a romantic idealisation or based on part-time work experience. In this assessment re-design, students experienced an aspect of the workplace of an academic beyond the lecturer's visible role as a teacher. We introduced this re-design in a subject with a traditionally heavy theoretical content which in science would normally be assessed in examinations; an activity that is not found in a workplace. Using the basic premise of a meta-study we were able to create a professional working environment for students that allowed them to experience the 'real thing'. It was pleasing to see how students produced new knowledge from the secondary research they conducted. They were clearly motivated by the challenge of a meaningful task that had a tangible outcome, a peer-reviewed student research journal. At the same time, students engaged in self-study and applied the theoretical content learned in the lectures, in a scenario that supports a better learning experience than two summative examinations. We believe the general framework of a group-based, meta-study approach with a peer-review process could be transferred to other STEM subjects, especially those with a heavy theoretical component.

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