Explicitly teaching teamwork and written communication within a problem based curriculum: Development of a generalised framework

David W Holmes[a]; Michelle Lasen[b].
School of Chemistry, Physics and Mechanical Engineering, Queensland University of Technology, Brisbane, QLD, Australia[a], Learning, Teaching and Student Engagement, James Cook University, Cairns, QLD, Australia[b]
Corresponding Author Email: d.holmes@qut.edu.au

SESSION

C1: Integration of theory and practice in the learning and teaching process

CONTEXT

Recent years have seen the growing importance of employability skills for engineering graduate success. Beyond disciplinary specific capabilities, employers increasingly expect graduates to be proficient in skills that are transferable across employment contexts; specifically, “the ability to communicate, collaborate and operate effectively within an industry environment” (Deloitte Access Economics, 2014, p. 3). However, there are concerns that current undergraduate programs, both in Australia and internationally, are producing graduates without the requisite proficiency in employability skills to flourish in their profession. According to the European Commission (2015), “the successful development of [employability] skills requires an education system capable of preparing students through more active and problem-based learning approaches, using assignments from the ‘real world’ and including support for risk taking and creativity” (p. 4). Nonetheless, within a problem based curriculum, skills development must be explicit. In particular, teamwork skills are “not likely to emerge spontaneously” (Hughes and Jones, 2011, p. 60). Effective implementation of explicit skills development within a problem based learning environment (PBL) remains an open research question.

PURPOSE

This paper reports on the development of a generalised pedagogical framework for explicitly scaffolding written communication and teamwork skills within a PBL curriculum.

APPROACH

Over several years, employability skills development within an Australian mechanical engineering degree program was evaluated using curriculum mapping, student performance, and staff and student feedback. This evaluation reviewed employability skills needs of graduates, and investigated why such skills were being underdeveloped within the curriculum, despite widespread application in learning and assessment tasks. Evaluation findings informed the development of a pedagogical framework, designed to explicitly address the employability skills shortfall within a PBL curriculum.

RESULTS

The study highlighted that the development of written communication and teamwork skills were largely assumed within the engineering degree program. Learning modules or experiences devoted to developing these skills were either rare (as with written communication) or largely absent (as with teamwork). Additionally, many large projects utilising these skills comprised a single, culminating assessment task, without opportunity for students to reflect on skills development or apply instructor feedback from one task to the next. Hence, a PBL subject structure was developed, integrating explicit instruction on written communication and teamwork, and allowing scaffolded reflection and performance enhancement within a single teaching period to assure learning.

CONCLUSION

The PBL framework intentionally scaffolds written communication and teamwork skills within a single subject, making possible accelerated and contextualised employability skills development. This framework has applicability across subjects, year levels and disciplinary contexts.

KEYWORDS

PBL; teamwork; written communication; employability skills; pedagogical framework.

Introduction

International trends in higher education have seen growing emphasis on embedding employability skills within curriculum (Arkoudis, Baik, Bexley, and Doughney, 2014; Scott, 2016; Yorke, 2006; Yorke and Knight, 2006). Beyond disciplinary-specific knowledge and skills, graduates are increasingly expected to be proficient in a range of skills that are widely applicable and transferable across employment contexts and suitable for life-long learning (Matthews and Mercer-Mapstone, 2016; Office of Parliamentary Counsel, 2015). Recent research into Australian employer perceptions revealed the critical role of employability skills for STEM graduates – in particular, "the ability to communicate, collaborate and operate effectively within an industry environment" (Deloitte Access Economics, 2014, p. 3). Nonetheless, there remain concerns both within Australia and worldwide that current undergraduate programs are producing graduates without the requisite proficiency in employability skills to be successful in their profession (Arkoudis and Doughney, 2014; Norton, Sonnemann, and Cherastidtham, 2013; Shah and Nair, 2011). The 2014 European Union (EU) Skills Panorama report highlighted findings from employer surveys, indicating that a proportion of STEM graduates exit universities under-skilled in communication, team-working and time management and organisational skills (European Commission, 2015, p. 4).

The current shortfall in employability skills development has led to broad calls and legislative imperatives for curriculum reform (Office of Parliamentary Counsel, 2015). Systematic approaches to teaching and assessing such skills within the context of the discipline, however, present challenges for academics (Arkoudis and Doughney, 2014; Arkoudis, 2014; Matthews and Mercer-Mapstone, 2016). Widening participation in higher education has meant that academics engage students with more diverse educational backgrounds and levels of preparedness for academic studies (Arkoudis and Doughney, 2014; Norton et al., 2013). While the research literature indicates that academics are concerned about their students' communication skills, they do not believe they have the time and expertise to address explicit skills development within curriculum (Baik, 2010; O'Loughlin and Arkoudis, 2009). More holistic pedagogies appear to be needed but their implementation cannot come at the expense of the disciplinary-specific fundamentals that underpin any career in STEM.

According to the European Commission (2015), "the successful development of [employability] skills requires an education system capable of preparing students through more active and problem-based learning approaches, using assignments from the 'real world' and including support for risk taking and creativity" (p. 4). The implementation and benefits of active learning pedagogies for disciplinary-specific skills development in the STEM fields are well documented (de Graaff, 2004; Frank, Lavy, and Elata, 2003; Mills and Treagust, 2003). Active approaches like problem based learning (PBL) have been shown to improve student engagement, student achievement, and skills retention (Freeman et al., 2014; Prince, 2004). However, an intrinsic link between PBL and improved employability skills, such as communication and teamwork, is less well established.

Kashefi, Ismail, and Yusof (2012) investigated the effectiveness of blended learning strategies, including active group tasks, on developing communication and teamwork skills within a multivariable calculus engineering subject. While they identified a modest improvement in students' communication skills throughout the subject, they saw no difference in students' teamwork skills, despite the variety of group tasks. Frank et al. (2003) reviewed implementation of PBL within a freshmen engineering subject and similarly found that team performance was poor in the absence of formal instruction in teamwork skills. A variety of other researchers (Colthorpe, Rowland, and Leach, 2013; Loughlin, 2013; Mort and Drury, 2012) agree that communication and teamwork skills must be intentionally developed within any active learning experience to achieve meaningful improvement. In particular, effective teamwork skills are "not likely to emerge spontaneously" (Hughes and Jones, 2011, p. 60.). There is extensive research literature that outlines strategies for explicitly teaching English language skills (e.g. Arkoudis 2014; Arkoudis and Doughney 2014; Colthorpe et al.

2013; Mort and Drury 2012) and teamwork skills (Hughes and Jones, 2011; Loughlin, 2013; Loughry, Ohland, and More, 2007; Page and Donelan, 2003; Riebe, Roepen, Santarelli, and Marchioro, 2010). While syllabus level frameworks like the CDIO (Crawley, Malmqvist, Lucas, and Brodeur, 2011) outline best practice with respect to a PBL focussed engineering curriculum, there remains a gap in the research on how to specifically structure effective employability skill development within a single PBL subject.

The development and evaluation of a pedagogical framework that specifically embeds formal written communication and teamwork skills development within a problem based curriculum will be the focus of this paper. The framework has been developed and implemented within a first-year introduction to engineering subject, but has applicability across university subjects, disciplines, and year levels. The remaining sections of this paper detail the curriculum evaluation that led to the development of the framework, outline the framework itself, and provide preliminary conclusions on the effectiveness of the approach.

Curriculum Evaluation

The pedagogical framework developed in this work emerged and evolved over several years in response to specific skills gaps identified within the curriculum of an Australian mechanical engineering degree program. The skills shortfall was highlighted by the significant challenges many later-year engineering students experienced when undertaking team-based project work, despite having completed numerous team-based learning tasks in preceding subjects. Challenges largely arose due to poor application of fundamental teamwork skills, including communication; time, task, and document management; and meeting organisation protocols. It became apparent that the requirement for students to work in teams throughout their degree was not sufficiently building their capacity for effective teamwork.

Upon further inspection, it was also apparent that elements of written communication skills development were implemented unsuccessfully throughout the curriculum. Unlike teamwork skills, modest improvements in written communication were evident during progression, but these improvements were considerably less than expected given the prevalence of written assessment throughout the program. It became clear that the strategies employed to develop key employability skills within the mechanical engineering program were either ineffective or inefficient, and further investigation was needed.

As part of a whole-of-program review, a detailed mapping exercise was carried out following the process of Holmes, Sheehan, Birks, and Smithson (2017). Metrics relevant to teamwork and written communication skills development are highlighted in Table 1. A significant disconnect between instruction and assessment is evident. In addition, it was found that assessment of teamwork and written communication occurred through many small tasks or elements of larger tasks, with limited opportunity for deep and authentic evaluation of skills development. The mapping exercise highlighted a clear need to better align instruction and assessment within subjects, and to develop and assure skills in a progressive and coherent way across the whole-of-program (Nightingale, Carew, and Fung, 2007; Orey, 2010).

Table 1: Curriculum mapping results specific to teamwork and written communication skills development (based on evaluation of the 28 subjects in the mechanical engineering major).

Employability skill	Number of subjects with formal instruction on skill	Total hours of formal instruction on skill	Number of subjects with specific assessment on skill	Proportion of all assessment in mech. eng. major devoted to skill
Teamwork	1	0.2	13	1.87%
Written Communication	3	3	21	7.21%

Learning experiences typically unfold in stages. Hughes and Jones (2011) identified teaching, practice, and feedback stages. Fink (2013) outlined an holistic view of active learning, involving three aspects: i) information and ideas, ii) experiences, and iii) reflection. Combining these elements, we propose the recursive four-stage process of Figure 1. Here, theory, practice, assessment and feedback, and reflection are identified as key elements of learning. Notably, the repetition of the learning process realises increasing complexity and depth. In this way, scaffolding of a skill or competence is achieved.

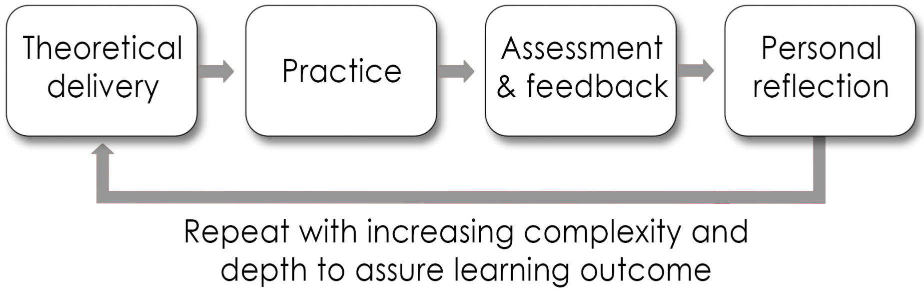

Figure 1. Flowchart representing an effectively staged and scaffolded learning process.

Importantly, within many subjects in the focal mechanical engineering program, assessment of skills was observed to occur through a single culminating assessment task (such as a project). While the full recursive learning cycle was assumed by academic staff to be occurring over a sequence of multiple subjects, there was little evidence to support this assumption. Both the findings of the curriculum review (Table 1), and the skills gap demonstrated by later-year students suggested to the contrary. As such, it was determined that curriculum changes were necessary to ensure appropriate skills development, and that intentional and effective scaffolding should feature as a key aspect of the redevelopment.

While comprehensive, program-wide redevelopment was attractive, it was infeasible in the context. Instead, improvement of key subjects was chosen as the most effective solution. In the first instance, the first-year introduction to engineering subject was chosen for redevelopment to address the skills shortfall and better prepare students to successfully engage with subsequent program work. Problem based learning (PBL) (Mills and Treagust, 2003) was chosen as the primary pedagogical approach for the subject. In the process, a generic framework for scaffolding teamwork and written communication skills within any single PBL subject emerged; the framework is presented in the following section.

Pedagogical Framework

The proposed pedagogical framework intentionally scaffolds teamwork and written communication skills development alongside the disciplinary-specific content of a PBL subject. This scaffolding is achieved through focussed learning activities and two consecutive projects (Figure 2). Importantly, all learning in the subject occurs within the context of these two projects. With a view to broader application of the framework, it is anticipated that the balance of independent learning and prescribed teaching is context-dependent, based on the complexity of the subject's theoretical content and ability of the students. For example, Figure 2 shows a full suite of face-to-face classes (lectures, tutorials, and practicals) as appropriate for a first-year class where students are still developing independent learning skills. Higher-level subjects may reduce such class time in favour of more independently driven PBL. Either way, it is intended that instruction focuses on the development of both disciplinary-specific skills and the targeted employability or generic skills, to enable students to successfully engage with project activities. The projects are intended to be completed by students in teams. Teams are required to submit an associated report, and potentially produce an additional output like a design, performance, presentation, etc. It can be seen in Figure 2 that a select number of classes are devoted to explicitly teaching the teamwork and written communication aspects of the project.

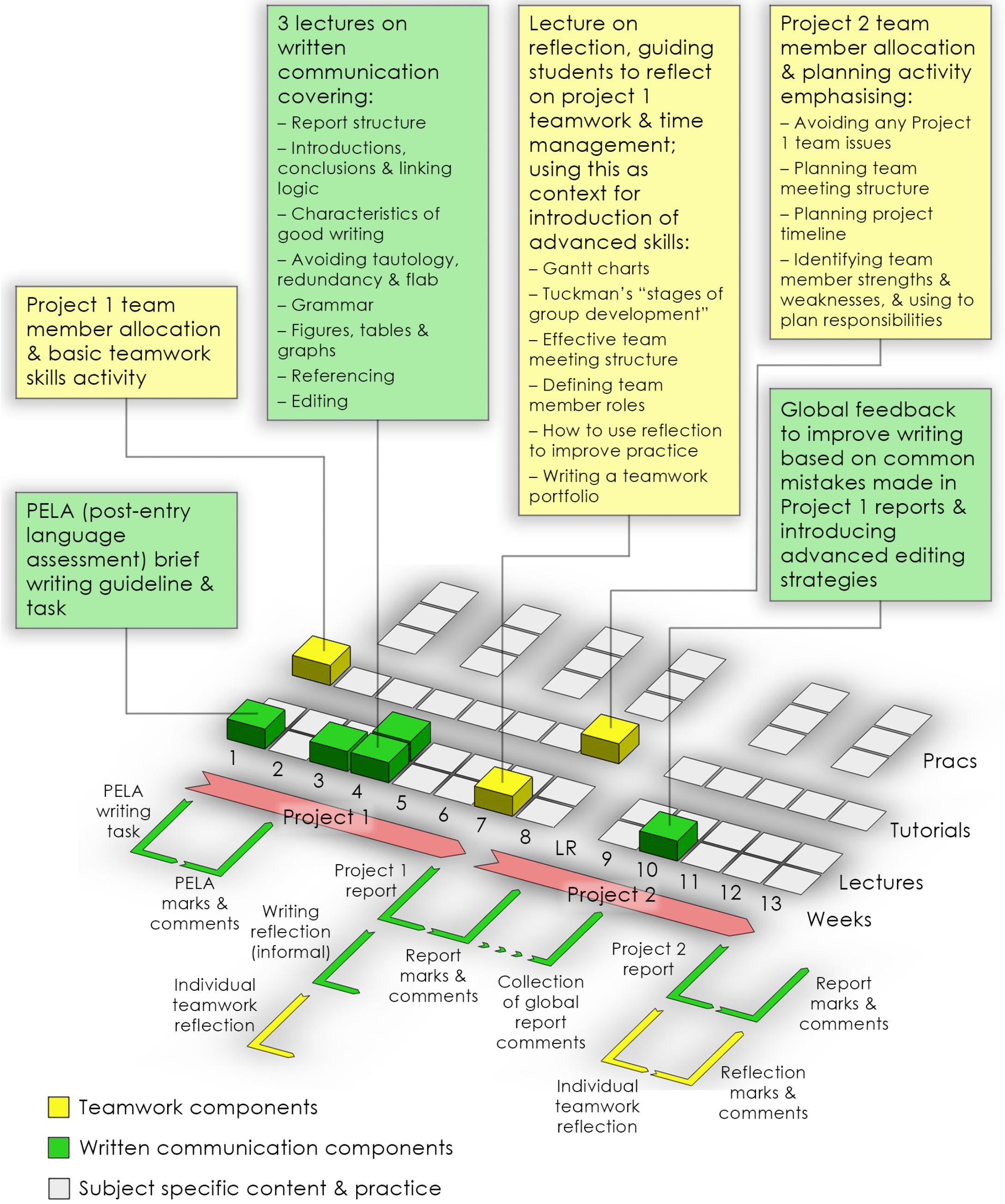

Figure 2. PBL subject structure for explicit scaffolding of written communication and teamwork skills (note LR refers to lecture recess and is a mid-semester break from formal teaching).

The two projects are intentionally staged in terms of the level of instructor guidance provided, and the complexity of the tasks. Classes are used to guide students through each project phase explicitly. In the case of a first-year implementation of the framework, a diagnostic post-entry language assessment (Arkoudis, 2014) is a valuable starting point to identify students that need additional writing assistance at the outset. Throughout the first project, an introduction to basic teamwork skills session is provided, and a set of written communication skill lectures is given in the middle of the timeline, as students are beginning to write their project report. Upon completion of project 1, a dedicated lecture instructs students on how to reflect on their performance, particularly in terms of teamwork, as well as to provide tools to improve the effectiveness of team meetings, management, and distribution of labour (see Loughry et al. 2007; Page and Donelan, 2003; Riebe et al. 2010; Woods et al. 2000). The students must also write an individual teamwork reflection focussing on their own performance as a team member against several important categories (Loughry et al. 2007).

For project 2, students are assigned new teams and given an opportunity to formally plan with their new team members how to capitalise on teamwork successes, and avoid the mistakes, of the first project. Project 2 focusses on a more complex and demanding task but may follow a similar procedure to project 1. Students are expected to demonstrate a higher level of creativity and independence compared to the first project and, as such, classes focus on advanced topics and skills. Importantly, feedback on the first project report is used as a mechanism to improve students' written communication skills in the second report. In addition to marks and comments provided for the first project report, a global feedback lecture is given identifying common mistakes and areas for improvement. Advanced editing skills are also outlined at this point (note, editing is generally observed as the area needing the greatest improvement after the first report). Again, this lecture is provided as students enter the writing phase of project 2. Upon project completion, students again submit a team report and a formal individual reflection on their personal teamwork performance. In this case, both the group report and individual reflection are marked and comments provided.

Assigning individual marks for group-based activities is a major challenge for academics and a cause of anxiety and animosity among students (Colthorpe et al. 2013; Riebe et al. 2010). In the proposed framework, marks are determined differently for the two projects. Given that the first project is heavily guided, and students complete much of the work during class time, each student in a team is assigned the same report grade (assuming sufficient class attendance). For the second project, which is conducted predominantly outside of class time, students complete a weekly timesheet detailing their project-related work hours. Each student must have their timesheets signed-off by all other team members on a weekly basis. Individual marks are calculated by scaling the group report mark based on individual contributions. This scaling sees hard working students receive higher marks, and less committed students, lower marks. Scaling can be simple and based on cumulative hours alone, or complex and based on hours contributed to an aspect of the project and the weighting assigned to that aspect. The introduction of a mechanism to identify and manage relative commitment and investment on the part of individual team members, and to provide assurances that those who complete the most work will achieve the best mark, ameliorates underlying animosities that accompany teamwork, or at least identifies and addresses tensions early. Timesheets also mirror how work is often measured in professional practice, adding a further 'real-world' feature to project activities.

The distinguishing feature of the proposed framework is the embedding of two complete cycles of the learning process, depicted in Figure 1, within a single subject. All four learning elements (i.e. theoretical delivery, practice, assessment and feedback, and reflection) are contained within each project cycle. So too, the enhanced complexity of project 2 ensures a scaffolding of targeted employability skills. Similar scaffolding and impact on student learning and achievement can be realised for the discipline-specific dimensions of the project work.

Conclusions

Implemented within a first-year introduction to engineering subject, initial evaluation of the developed PBL framework has seen it accelerate development of both employability and disciplinary-specific skills. While student consultations to address group issues had been common in the past, the improvement in student team skills has resulted in far less need for instructor intervention. In terms of written communication skills, clear improvements in quality, editing, and conciseness have been observed, with an evident increase in the class average mark for project 2. Quality of design work also consistently exceeds expectations. An enhanced student experience has also been observed with significant improvement in formal student survey scores, and excellent informal feedback on teamwork and the group projects generally. Formal evaluation of the effectiveness of the proposed pedagogical framework is presently underway and will be published in the future.

Following on from the initial success of the framework, advanced variants have since been implemented in later year design subjects, with a similarly positive impact on student outcomes. While currently in pilot implementation among the authors, the framework has also been packaged as an institutional exemplar of good practice within JCU professional development activities [link]. In this context, the approach has been positively received by academics from across the university, and enthusiasm is frequently expressed for a PBL structure that is conceptually simple and effective in employability skill development.

The framework developed in this work has been found to be a powerful way to deliver employability and discipline-specific skills development within a single PBL subject.

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