Using Curriculum Mapping to Articulate Transferable Skill Development in Science Courses: A Pilot Study

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Abstract

Work Integrated Learning (WIL) activities are designed to provide students with a range of opportunities to develop employability capabilities. Many of these capabilities are transferable skills. Embedding contextualized and scaffolded WIL activities throughout undergraduate science programs allows students to integrate disciplinary knowledge with industry practices and to develop non-discipline specific transferable skills without requiring industry placements. Integrating the development of core discipline knowledge with transferable skills in this contextualized setting will enhance the student experience and learning outcomes. Universities cannot teach all of the applications that exist, so the ultimate goal is to equip students with a stronger understanding and ability in the core discipline concepts and skills that, in conjunction with transferable skills, will enable graduates to 'learn on the job', and adapt to a wide range of employment opportunities. This paper reports on a process that maps the development of transferable WIL skills in a Chemistry major and identifies gaps in the curriculum where opportunities for skills development are missing. Suggested enhancements to the process include cataloguing relevant learning activities. This will provide academics with a useful resource that will facilitate the embedding of WIL into the curriculum.

Introduction

Work-integrated learning (WIL) aims to increase the employability of graduates by combining theoretical and academic study with work experiences (Kjellén & Svensson, 2014). Edwards Perkins, Pearce, & Hong (2015) identified the following common features of WIL definitions: "*Integrating theory with the practice of work; Engagement with industry and community partners; Planned, authentic activities; and Purposeful links to curriculum and specifically designed assessment*" (p.iv).

A general understanding is that a key component of WIL is work placement. However, for regional institutions, and institutions with a student cohort studying online this can prove challenging. There is not the diversity of relevant industries accessible in many regional areas, and the ability of students studying online to participate in work placements is often limited. Consequently, incorporating authentic WIL experiences into the curriculum is "a notable and growing challenge" (Edwards, Perkins, Pearce, & Hong, 2015, p. 55).

In a report on Science, Technology, Engineering and Mathematics (STEM) skills in the workforce, Prinsley and Baranyai (2015) reported that the skills and attributes most highly rated by the majority of employers surveyed were generic skills such as active learning (ability to learn on the job), critical thinking, problem-solving and interpersonal skills. The most highly ranked work-related skill was *Understanding how we do business*, which ranked sixth with just over 40% of employers listing this as very important.

Work-ready graduates should have a range of skills and knowledge, some of which can be acquired through work-placements, but many others can be acquired as part of students' undergraduate studies. They include workplace and occupation-specific skills and knowledge, a broad understanding of the nature of the relevant industry, self-understanding and awareness, foundational skills and knowledge (e.g., literacy, numeracy, learning strategies) (Edwards et al., 2015) and transferable skills. These are general 'all-purpose' skills that are relevant across all employment situations: such as critical thinking; teamwork; listening; time management; and leadership.

It is evident from this list that work placement alone is not sufficient to develop a work-ready graduate, and, depending on the type and quality of other WIL activities embedded in the curriculum, and the type of student, it may not even be necessary. For example, mature-aged students who have been working in the relevant industry may not require work-placement. Furthermore, if placements are not well-organised or authentic, they will contribute little to making a graduate work-ready.

In a review of the literature, Edwards et al. (2015) provide a range of activities that, in addition to placements, job-shadowing, internships and site visits, can be classified as WIL. These include case studies, simulations, role play, guest lecturers, use of commercial programming code and software packages, application of professional routines and procedures, reference manuals, field work, career-development learning and professional skills training, problem-based learning (PBL), virtual projects and simulations, undergraduate research, personal journals, mentoring and networking, panel sessions, and teamwork.

Context

The University of New England (UNE) is located in regional New South Wales, Australia. Approximately 50% of UNE science students study off-campus. As a consequence of its location and larger than average off-campus student cohort, improving graduate employability through WIL activities at UNE is more challenging than it might be for larger city-based universities with primarily on-campus students.

Some employers have raised concerns that chemistry graduates are unable to demonstrate many of the desirable transferable skills (Hanson & Overton, 2010; Sarkar, Overton, Thompson, & Rayner, 2016). Consequently, a key focus of this process was to identify opportunities for curriculum re-design in the Chemistry major to enhance learning opportunities within a WIL setting.

There are two main goals when developing employability capabilities in students at UNE. The first goal is to embed WIL activities throughout the program of study. The activities must be contextualized and scaffolded so that students can integrate disciplinary knowledge with industry practices, and develop non-discipline specific transferable skills without requiring industry placements. Secondly, the requirements of diverse student cohorts must be catered for. For example, one cohort of students may consist of young school leavers studying on-campus. Another cohort, enrolled in the same unit of study, may consist of mature-aged professionals enrolled off-campus, who wish to upskill their discipline knowledge. Background knowledge, work-experience and access to learning materials and support will differ greatly for these two cohorts.

This paper describes a pilot study that was designed to (i) generate interest in, and support for WIL in the sciences by engaging staff in discussion about WIL, (ii) identify the desirable transferable skills required for work-ready graduates and (iii) conduct a mapping of when and where transferable skills are taught, practised and assessed in the Chemistry major at UNE. This pilot will inform the design of a larger project to map transferable skills across all science-based degrees at UNE.

Identifying and mapping transferable skills

To create room in the curriculum for the development of transferable skills, we need to identify opportunities for curriculum re-design that focus on relevant core concepts and competencies. This requires a 'fine grain' picture of where and how transferable skills are currently being developed.

Curriculum maps can help identify how the curriculum promotes the development of skills, and identify gaps where opportunities for skills development are missing (Fallows & Steven, 2000). The mapping process used here was based on a process developed by Reid and Wilkes (2016) to map quantitative skills across STEM curricula at UNE. Reid and Wilkes aimed to help educators identify gaps and duplication in the teaching, practice and assessment of quantitative skills across programs. The main elements of the project included the identification of key graduate quantitative skills, the development of curriculum mapping tools to record in which unit(s) and at what level of attainment (roughly equating to first, second and third year of a bachelor program) each quantitative skill is taught, practised and assessed. The tool also allows identification of differences in the way quantitative skills are developed for on-campus and distance students. The mapping tool is freely available online at http://www.une.edu.au/qs-mapping.

For this pilot, we used the tool developed by Reid and Wilkes (2016), replacing the quantitative skills with transferable skills. The transferable skills were sourced from the non-discipline-specific Chemistry Teaching and Learning Outcomes (CTLO) (Pyke, O'Brien, Yates, & Buntine, 2014) (developed from the Science Learning & Teaching Academic Standards Statement (Jones, Yates, & Kelder, 2011) as part of an emerging national quality assurance environment), Sarkar et al. (2016), and consultations with staff (discussed below). Mapping of transferable skills in the Chemistry major was limited to which unit of study and which week in the trimester the particular transferable skill was taught, practiced and assessed. The capability of the tool to map the level of attainment was not utilized in this study. This will be introduced after evaluation and scale-up of the pilot process.

Workshop

The first step was to run a workshop with 35 academics from 15 scientific disciplines, across UNE's two science schools: the School of Science and Technology and the School of Environmental and Rural Science. Participants included the entire Chemistry department (i.e., 7 full-time academics), and a Learning Designer from the School of Science and Technology. The main aim of the workshop was to develop, in relation to UNE science courses, an overview and awareness of the following:

- The key issues (general or discipline-specific) related to embedding WIL into courses;
- The non-discipline specific skills that STEM graduates should possess;
- What staff are currently doing to embed WIL into courses;
- Ideas for embedding WIL into UNE courses.

The workshop began with a brief overview: (i) of how WIL is defined within the literature (Patrick et al., 2008) and by higher education institutions, (ii) of how WIL can be used as a tool for improving student employability and efficacy in the workforce, and (iii) why embedding and scaffolding WIL activities throughout our courses is a priority at UNE (see Introduction).

During the workshop, the attendees had the opportunity to discuss and record what they see as the main issues and impediments to embedding WIL throughout units and courses. This activity had two purposes. The first was to give staff a chance to vent any negativity or frustration that they may have regarding WIL, thereby moving the workshop toward an environment conducive to constructive discussion. The second was to obtain information about staff attitudes and specific concerns or issues, which would be useful in strategic planning, particularly in regards to getting buy-in from staff and implementing innovations or changes to the status quo.

The issues and challenges that academic staff felt they would face in trying to include WIL activities throughout the curriculum are summarized below:

- An increase in academic workload associated with the development and implementation of scaffolded WIL activities, across degree programs;
- How to assess whether the requisite skills are satisfactorily achieved;
- How to integrate WIL activities into an already crowded curriculum;
- Student resistance to being assessed on non-discipline specific skills (this is of particular relevance for mature-age students who may have already had one or two careers);
- Ensuring equity for on- and off-campus students being assessed on WIL activities.

In the next stage of the workshop, participants discussed what non-discipline specific transferable skills and knowledge science graduates should possess in order to ensure employability and flexibility in employment pathways. These were grouped into five categories and are summarized in Table 1.

Table 1: **Transferable graduate skills identified by UNE science academics.**

General Area	Examples
Cognitive Skills	Analytical skills; Critical thinking; Problem solving; Systems thinking; Experimental design; Risk analysis; Common sense
The World Outside University	Awareness of real world issues; Cultural awareness; Awareness of industry standards; 'Big picture' industry context; Societal concerns; Commercial awareness
Ethics (non-discipline specific)	Ethical behaviour; Work ethic
Interpersonal Skills	Leadership; Teamwork; Organizational skills; Time management; Listening; Presentation skills
Intrapersonal Skills	Creativity; Initiative; Autonomy; Confidence; Resilience; Engagement; Passion; Enthusiasm

Finally, workshop participants discussed what they were currently doing to embed WIL activities within units, identified gaps or deficiencies in their approach to developing transferable skills in graduates, and shared ideas for embedding WIL and addressing gaps. This was an opportunity to identify which academic staff, if any, were embedding WIL activities into their units. This last discussion also provided encouragement or inspiration for staff who were unsure (or unconvinced) about adjusting their curriculum to include formal development and assessment of transferable skills.

Overall, the workshop was successful in that staff came away enthused and with a positive attitude towards the planned mapping activities. For the authors, it was useful to gauge staff sentiment toward WIL and the mapping of transferable skills. This informed the formulation of a plan that aimed to maximise staff buy-in and facilitate a successful implementation of the mapping exercise.

Pilot mapping exercise on the UNE chemistry major

The workshop and planning stage were followed by a pilot study to map transferable skills within the Chemistry major at UNE. Prior to the mapping exercise, Chemistry teaching staff were asked to provide details (via a pen and paper survey) on the following:

- History of industry experience, i.e., had staff worked outside academia or in any role not directly related to scientific research or chemistry laboratory work;
- Supervision history of Honours or Postgraduate students;
- Understanding of WIL;
- Personal view on how WIL relates to graduates who *will not* undertake postgraduate study;
- Personal view on how WIL relates to graduates who *will* undertake postgraduate study;
- What transferable skills graduates at bachelor level should possess;
- Whether or not staff incorporate WIL into their teaching.

There were several reasons for collecting this information. Firstly, it provided the opportunity to identify any transferable skills that had not been already identified during the workshop or listed in the CTLOs. The CTLOs are based on the Australian Learning and Teaching Council (ALTC) Learning and Teaching Academic Standards Statement for Science (Jones, Yates, & Kelder, 2011) and contain TLOs for discipline specific skills and knowledge and transferable skills.

As with the workshop, this was an opportunity to gain some insight into which staff, if any, were currently embedding WIL activities into their units. It was also an opportunity to provide encouragement or inspiration for staff who were unsure (or unconvinced) about adjusting curriculum to include formal development and assessment of transferable skills. Finally, it was useful to gauge staff sentiment toward WIL and the mapping of transferable skills. Consideration of these factors ensured the implementation of the mapping exercises had the best chance of success.

The survey revealed that the Chemistry academics had minimal industry experience. One staff member had undertaken mandatory work placements at the end of their undergraduate degree and another had undertaken some casual work in commercial laboratories between academic appointments. Another staff member had held professional roles within commercial areas of industry, and had also worked as a research scientist in a field unrelated to chemistry.

While Chemistry staff reported that WIL activities were incorporated in their units, there was a large differential in staff perception of their understanding of WIL, as well as the importance placed on the development of transferable skills. In answer to '*What is your understanding of WIL*?' answers ranged from several that expressed very clear (albeit different) definitions to one answer of "My understanding of WIL is rudimentary at best. I consider it primarily a buzzword du jour that is part of [a] narrowly utilitarian vision of higher education". In answer to '*How does WIL relate to your graduating students who will not undertake postgraduate study'* responses were either "Not Sure" or "Very relevant" and in answer to '*How does WIL relate to your graduating students who will undertake postgraduate study'* answers were either "Not Sure", "Somewhat relevant" or "Very relevant". The potential significance of the staff experience and attitudes will be discussed in the Results section below.

The survey revealed no previously unidentified transferable skills. The final list of transferable skills included in the pilot mapping of the Chemistry major are listed in Table 2.

The unit mapping was completed using the tool described above in the section following the Introduction. While each unit offered by the Chemistry discipline was mapped by the relevant unit coordinator, the mapping was completed in a group setting. This allowed for discussion and clarification about the meaning of the CTLOs, skills and terminology used within the mapping tool, resulting in a more consistent approach to the mapping by the academic staff.

Table 2: **Transferable skills that were included in the pilot mapping exercise.**

Transferable Skill	Source
Understand ways of scientific thinking by recognising the creative endeavour involved in acquiring knowledge, and the testable and contestable nature of the principles of chemistry	CTLO 1.1
Understand ways of scientific thinking by recognising that chemistry plays an essential role in society and underpins many industrial, technological and medical advances	CTLO 1.2
Understand ways of scientific thinking by understanding and being able to articulate aspects of the place and importance of chemistry in the local and global community	CTLO 1.3
Communicate chemical knowledge by presenting information, articulating arguments and conclusions, in a variety of modes, to diverse audiences, and for a range of purposes	CTLO 4.1
Communicate chemical knowledge by appropriately documenting the essential details of procedures undertaken, key observations, results and conclusions	CTLO 4.2
Take personal, professional and social responsibility by demonstrating a capacity for self-directed learning	CTLO 5.1
Take personal, professional and social responsibility by demonstrating a capacity for working responsibly and safely	CTLO 5.2
Take personal, professional and social responsibility by recognising the relevant and required ethical conduct and behaviour within which chemistry is practised	CTLO 5.3
Leadership	Workshop
Initiative	Workshop
Resilience	Workshop
Confidence	Workshop
Commercial Awareness (in addition to CTLO 1.2)	Workshop
Interpersonal Skills (in addition to discipline specific communication skills and personal responsibility outlined in CTLO's 4.1, 4.2, 5.1 and 5.2 0	Workshop
Risk Analysis	Workshop
Ethical Behaviour (in addition to CTLO 5.3)	Workshop

Results and discussion

Results from the mapping indicated that neither leadership nor initiative skills were taught, practiced or assessed in any Chemistry unit. All other transferable skills listed in Table 2 did appear within the mapping, although there were only a few instances of each, and their development was not scaffolded across the major. Evidently, transferable skills are not being adequately taught, practised or assessed within the Chemistry major.

However, as discussed previously, Chemistry staff had reported that WIL activities were provided in most units within the major. Therefore, there seemed to be a disconnect between what staff perceive they are doing when asked generally about their WIL activities as opposed to when they are asked about specific transferable skills (via the fine-grain mapping).

During the mapping exercise, there was much discussion about the teaching of chemistry. Based on those discussions, and the additional comments that staff entered into the mapping spreadsheet, there is evidence that students are implicitly exposed to the development of transferable skills. The anecdotal evidence suggests that student development of transferable skills is a result of the teaching practices of Chemistry staff but that these activities are not explicitly described, nor scaffolded and generally are not assessed.

For example, the process used to provide formative feedback in the laboratories to help develop students' confidence in the laboratories is Socratic in nature; that is responding to student questions with a leading question. This provides guidance toward the next step in solving the problem, and helps the student to feel some confidence that they are on the right track. This not only helps the student answer the question by themselves, thereby developing their problem-solving skills, but it also increases self-confidence. It teaches students how to step through a problem and to have confidence in doing that; therefore they develop the belief that they can resolve the questions or queries for themselves.

Modelling persistence and resilience is another example. Teaching staff remain calm and positive but persistent and resilient in the face of student negativity and sometimes anger. A chemistry-teaching laboratory can be a very stressful environment for students and staff. Students are required to simultaneously understand theoretical concepts, learn physical techniques, and then ultimately connect the macroscopic technique to the microscopic chemical concept. Additionally, there is the physical demand of trying to achieve this in a short four-hour window, whilst standing at a bench. Staff deflect student negativity and stress, demonstrate patience in teaching by reflecting back to the student a positive demeanour. When staff persist with a stressed and negative student in this way, we see the physical demeanour and frame of mind of the student change. Demonstrating persistence and resilience when helping students in turn helps our students to develop the same traits.

Initiative and understanding of commercial research and development are implicitly developed in mandatory laboratory sessions in some of our Chemistry units. In one unit, students are taught how to make a range of sensors to detect acids and bases. They are provided with testing equipment, but have to develop the testing protocol themselves. In another unit, students are asked to develop a theoretical synthesis route and experimental procedure to produce molecules that have not been previously published.

Examples of teaching and learning activities that help students develop transferable skills occurred throughout the Chemistry major. More 'traditional' transferable skills, such as teamwork and problem solving are clearly listed as learning outcomes in most courses and units. However, skills such as confidence, resilience and initiative, which *are* being integrated and contextualized, are not explicitly listed as learning outcomes, nor are they assessed or scaffolded, and were not identified as part of the mapping process.

Activities where students are developing transferable skills such as resilience and confidence, without the students', or even the academics', awareness, can be thought of as 'hidden WIL' (Chuck, Jones, Millar, & van Reyk, 2016). An alternative process that would help identify where these 'hidden' transferable skills are developed would be to map specific activities, as opposed to the skills themselves. We propose developing a catalogue of activities that develop transferable skills, and utilize the tool to map those activities. As the mapping tool would include specific activities or scenarios, we hypothesize that staff would easily be able to answer 'yes' or 'no' as to whether they utilize that kind of activity. This process would make it easier to determine where and when transferable skills are being developed within units and programs.

Developing a catalogue of activities would include discussion with academic staff and industry representatives, and observation of teaching activities. Input from experts in learning, teaching, and employment (such as Educational Psychologists, Education and Human Resource academics) would prove useful when identifying learning activities that develop transferable skills. The fact that Chemistry teaching staff had little industrial or commercial experience may explain why there appears to be primarily implicit development of transferable skills. Given that historically the main focus of discipline teaching staff is the transfer of discipline specific knowledge and skills, it seems feasible that academics are not aware that transferable skills are being developed by students during prescribed learning activities. Another possibility is that staff may believe these skills are being developed, and therefore think the skill development is obvious to students. Given that most of our students (undergraduate and postgraduate) will be working in industrial or commercial roles, raising awareness of the development of these skills within certain leaning activities is of fundamental importance.

We suggest that mapping the learning activities that develop transferable skills, rather than the skills themselves, would help staff better articulate the development of those skills to their students.

A catalogue of learning activities could be developed that would include:

- Information about which transferable skill each activity helps develop;
- Instructions/suggestions on how to articulate the skill development, not only through statements of learning outcomes but also through discussion with students during the learning activities;
- Information and resources on how to assess and scaffold the learning outcomes associated with each activity.

Essentially this would be a 'tool box' for embedding WIL activities.

Linking the activities to a digital badging protocol could help to make the hidden WIL visible. Digital badging is useful because the badges give enhanced visibility to the many formal and informal learning scenarios students engage with during the course of their studies, but which may not be immediately obvious to someone reading a degree transcript (Seery et al., 2017).

Ultimately, the collection of digital badges could lead to conferral of a 'passport' detailing the cross-disciplinary, transferable skills students have obtained throughout their undergraduate science degree.

Earning badges to identify skill achievement is certainly not a new idea. Although utilization of digital badging is currently limited within the Australian tertiary education system, digital badging in education has been utilized for recognition and motivation in student acquisition of chemistry laboratory skills in the USA and UK (Hennah & Seery, 2017; Seery et al., 2017; Towns et al., 2015). It is also currently being investigated as a tool for student recognition of transferable skills at Monash University in Australia and the University of Warwick in the UK (Hill, Overton, & Brookes, 2017; Hill, Overton, Thompson, & Kitson, 2018).

Conclusion

The data from the transferable skills mapping tool did not achieve the goal of providing a fine-grain curriculum map of where and when transferable skills are taught, practised and assessed, across the Chemistry major. Furthermore, the results indicated that there was a lack of activities that develop transferable skills in our students in a comprehensive manner. However, staff surveys, discussions among staff whilst undertaking the mapping, and comments entered into the tool, provided evidence that activities that develop transferable skills are occurring throughout the major, albeit in an ad hoc manner.

Ultimately, we would like to create a catalogue of learning activities that develop transferable skills, and map those skills across the curriculum. We hypothesise that such a process would not only uncover the instances where transferable skills are being developed across the curriculum, but also provide a simpler and clearer path (i.e., useful resources) for staff to embed WIL activities into their majors.

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