Improving the assessment of transferable skills in chemistry through evaluation of current practice

Abstract The development and assessment of transferable skills acquired by students, such as communication and teamwork, within undergraduate degrees is being increasingly emphasised. Many instructors have designed and implemented assessment tasks with the aim to provide students with opportunities to acquire and demonstrate these skills. We have now applied our previously published tool to evaluate whether assessment tasks allow students to demonstrate achievement of these transferable skills. The tool allows detailed evaluation of the alignment of any assessment item against the claimed set of learning outcomes. We present here two examples in which use of the tool provides evidence for the level of achievement of transferable skills and a further example of use of the tool to inform curriculum design and pedagogy, with the goal of increasing achievement of communication and teamwork bench marks. Implications for practice in assessment design for learning are presented.

Introduction

The importance of undergraduate students acquiring essential transferable skills such as communication, teamwork, problem solving and leadership (sometimes called "soft skills" or "professional skills") has been emphasised in many industry (Confederation of British Industry 2016; Hager, Holland, & Beckett 2002), and academic reports (Heckman & Kautz 2012; Robles 2012; Sarkar, Overton, Thompson, & Rayner 2016). Recognising their importance, most institutions in Australia now list a set of graduate attributes (also called graduate outcomes, graduate capabilities and related terms) that a graduating student will have (Barrie 2004).

Further evidence of the increasing attention being paid to the transferable skills that students should acquire during their degree is reflected in national and transnational efforts worldwide. In Europe, the guidelines for application for the prestigious Eurobachelor label specify a list of generic competences among the required learning outcomes of a degree (European Chemistry Thematic Network 2016). Similarly, the American Chemical Society's guidelines for evaluation of degree programs list a set of skills of this type that should be developed during the degree (Committee on Professional Training 2015). In Australia, the set of Science Threshold Learning Outcomes (TLOs), and the discipline-specific Chemistry Threshold

Learning Outcomes (CTLOs) derived from the Learning and Teaching Academic Standards (LTAS) project (Jones, Yates, & Kelder 2011; Pyke, O'Brien, Yates, & Buntine 2014) include transferable skills. The CTLOs have been adopted by the Royal Australian Chemical Institute (RACI) for professional accreditation of chemistry degrees in Australia.

Some institutions have implemented specific programs to target transferable skills, including within science (Peat, Taylor, & Franklin 2005) and chemistry degrees (Loshbaugh, Laursen, & Thiry 2011; Towns 2010). However, the definition and implementation of transferable skills as graduate attributes remain difficult (Green, Hammer, & Star 2009). Those authors suggest that the attributes should be embedded holistically, through a whole-of-institution approach. An alternative holistic approach focused on the ongoing personal development of the student has also emerged (Hill, Walkington, & France 2016), exemplified by the development of these attributes occurring "through intentional movements [by the student] assisted by institutional arrangements" (Su 2014). This approach is supported by structured programs that culminate in well-designed capstone units (Lee & Loton 2015; Spronken-Smith et al. 2016). As an Australian example, the University of Sydney stated in its Strategic Plan 2016-2020 that a university-wide approach to assessing graduate qualities will be developed (The University of Sydney 2016). Achievement against these attributes will be reported for every student at the completion of their degrees.

In spite of this recognition of the importance of transferable skills and the efforts listed, it is clear that many students graduate without the ability to apply these skills in the workplace (Confederation of British Industry 2016; Hager et al. 2002; Sarkar et al. 2016). As Bodner (2016) said in a plenary lecture, "they are called soft skills because they are so hard to develop". Similarly, Knight (2007, p.1) has referred to these skills as "wicked competences", because "they resist definition, shift shape and are never 'solved'". Thus, further effort is required to develop methods to ensure that students have achieved desired attributes upon graduation.

Assessment has a critical role in the student learning experience (Ramsden 2003) and can be designed to equip students for life-long learning (Boud & Falchikov 2006). In addition, it is known that from the students' perspective, assessment defines the course (Gibbs & Simpson 2004). Thus, it can be argued that if graduate attributes are not assessed, they will not be taken seriously by students (Knight & Page 2007, p.11). Following over a decade of work exploring the definition and assessment of graduate attributes (Barrie, Hughes, Crisp, & Bennison 2012), Barrie and colleagues have argued that embedding these skills within compulsory assessment provides the strongest evidence for their achievement (Hughes & Barrie 2010). Similarly, because graduate attributes are typically written using ambiguous language, Sadler (2015) argues for the use of assessment to define the expectations of a course. He writes

...assessment tasks and specifications are material formulations that can be exhibited, argued about and administered. They provide the sharpest and most

direct tool available for discussing, clarifying and communicating course intentions for students and academics alike. (p. 5)

Thus, assessment is a starting place to reform the design of teaching, particularly for transferable skills.

In the Australian context it has been reported that although a majority of academic staff know graduate attributes are important, they do not translate this into their teaching practice (de la Harpe & David 2012). While many provide opportunities for students to gain these skills, they are unlikely to assess them adequately. In a comprehensive report on the assessment of transferable skills, Knight and Page (2007) noted that they can be characterised as “achievements that cannot be neatly pre-specified, take time to develop and resist measurement-based approaches to assessment”. Surprisingly, those authors found that many academic staff did not perceive the difficulties in assessing such skills. Improving the ability of academic staff to evaluate the effectiveness of their assessment items could help ameliorate this situation and give them confidence in the design of their assessment items.

The authors constitute the project team for the Office of Learning and Teaching (OLT) funded project “Assessing the assessments: Evidencing and benchmarking student learning outcomes in Chemistry,” OLT 14-3562. This project derives from the development of the Chemistry Threshold Learning Outcomes (CTLOs) (Pyke et al. 2014). Preliminary work on application of the CTLOs to existing programs of study showed that demonstrating their achievement was not straightforward (Schultz, Mitchell Crow, & O'Brien 2013). This project seeks to support academic staff by examining the extent to which their assessment measures the intended learning outcomes, and by providing examples of high quality assessment items. Outcomes from this project align with Sadler's (2015) call for reform in assessment, particularly reform of the design and specification of assessment tasks.

Using intended learning outcomes as the basis to design curriculum, assessment tasks, and learning activities is recognised as optimal practice (Biggs 1996; Wiggins & McTighe 2005). Within this approach to instructional design, the first step is to identify the intended learning outcomes, then identify the method of assessment to determine what constitutes acceptable evidence of students’ achieving these outcomes. Finally, the learning experiences and instruction are planned to provide students with the opportunity to acquire the knowledge and/or skills that will meet the intended learning outcomes. Application of a verification tool to evaluate the alignment of the assessment items in measuring students’ achievement can assist instructors to ensure that those assessment methods are adequate (Figure 1).

Figure 1. Application of an evaluation tool within the backwards design process.

An overall goal of the Assessing the Assessments project was to provide academic staff with a tool to diagnose whether a particular assessment item allows students to demonstrate the achievement of a specific learning outcome. The tool can either be applied retrospectively to benchmark assessment, or proactively to inform the planning and design of teaching and assessment. This tool was developed for a specific set of learning outcomes, the CTLOs, but it can be applied to any desired learning outcome or graduate attribute (Schmid et al. 2016). In this chapter, we report the application of the tool to evaluate two specific CTLOs that target transferable skills: communication (CTLO3.5) and teamwork (CTLO4.1), and illustrate it with three assessment items that have been implemented in upper level chemistry classes.

There are several dimensions in each CTLO expressed as a second tier (Pyke et al. 2014) and we are considering the following specific second tier CTLOs:

3. Investigate and solve qualitative and quantitative problems in the chemical sciences by:

3.5: Demonstrating the cooperativity and effectiveness of working in a team environment.

4. Communicate chemical knowledge by:

4.1: Presenting information, articulating arguments and conclusions, in a variety of modes, to diverse audiences, and for a range of purposes.

These learning outcomes frame the skills that they address specifically in the discipline of chemistry and the chemistry degree. This may lead to differences in outcomes of evaluations of assessment items between applying the CTLOs compared with a set of generic institutional graduate attributes that are not situated within their discipline context.

We have selected CTLOs 3.5 and 4.1 in particular, because teamwork and communication appear ubiquitously in every published list of transferable skills, graduate attributes and generic competences, are cited as highly desired by employers (Sarkar et al. 2016), yet are frequently poorly assessed. Our initial overview mapping of chemistry degrees in Australia in 2012 showed that CTLO4.1 was only addressed in few units (1-3) in a typical chemistry program (Schultz et al. 2013). That mapping exercise did not evaluate individual assessment items and at that time CTLO3.5 had not been included as a second tier item.

As described in our report of development of the tool, when evaluating submitted assessment items, it was observed that many academic staff assumed that participation in any activities with peers enabled acquisition and assessment of teamwork skills (Schmid et al. 2016). The terms 'group work' and 'teamwork' are used interchangeably (Johnson & Johnson 2009; Johnson, Johnson, Ortiz, & Stanne 1991) so the label alone does not determine whether the item allows students to demonstrate the CTLO. It is therefore important to evaluate assessment of the specific skills gained by students within an activity. Within science faculties in Australia, teamwork skills tend to be poorly taught and rarely assessed and few academic staff are properly trained in this area (Dunne & Rawlins 2000). Moreover, as described above, both cooperativity within effective teamwork skills and communication skills have been proven difficult to assess via standard assessment methods typically employed in universities (Knight & Page 2007). Consideration of these two skills together lends the opportunity to design learning activities in which both can be developed and demonstrated. That is, students have the opportunity to work cooperatively in a team for particular tasks, and part of the activity involves some form of communication of their outcomes or findings to others within or beyond the team.

The research questions answered by this study are:

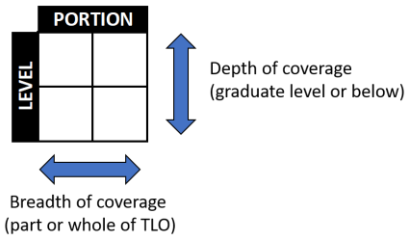
- To what extent can a tool assist academic staff to judge whether their assessment tasks allow students to demonstrate transferable skills, in particular communication and teamwork?
- How can use of a tool assist in the instructional design of assessment methods and aligned learning experiences?

We provide three case studies submitted by members of the project team exemplifying assessment items that allow students to demonstrate achievement of teamwork and communication skills.

Results and discussion

The process of designing the tool to evaluate assessment items has been reported (Schmid et al. 2016) and a summary is available at the project website http://chemnet.edu.au/assessment. The outcome of that process is a series of four-square grids for each CTLO plus an assessment rating, shown in Figure 2 and Table 1. Each grid in Figure 2 is shaded by the evaluator to reflect the level to which an assessment item confirms a specific learning outcome (either to developing or at graduate level) on the vertical axis, and how much of the stated learning outcome it addresses (partial or whole) on the horizontal axis.

Figure 2. Evaluation tool for an assessment item against a specific learning outcome



The evaluator then applies an assessment rating according to the extent of the alignment; the levels of attainment are: A (addressed), D (demonstrated) or C (credited i.e. assessed) as given in Table 1. This is a refinement of our previously published version of the tool, based on our experiences evaluating a set of items.

Table 1. Assessment ratings in the tool that describe the level of attainment.

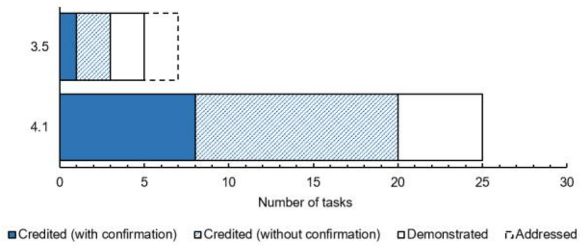
Evaluation result		Description
A		The learning outcome is addressed, but students are not required to demonstrate their capability.
D		Students are required to demonstrate their capability, but are not credited based on that demonstration.
C		Students are credited based on their demonstrated capability, but a passing grade can be achieved without that credit.
		Students are credited based on their demonstrated capability, and that credit is a necessary requirement for a passing grade (confirmed).

The tool is designed for use with single assessment items (which can then be examined collectively) rather than a suite of assessment items. Nonetheless evaluation with the tool can be a powerful motivation for change of a set of learning activities and corresponding assessment, as shown through the first example below.

Application of the tool

As part of the Assessing the Assessment project, 45 items were submitted by Australian chemistry academic staff for evaluation by the project team. It was found that only eight of the items specifically addressed CTLO3.5 and of these, credit was given for achieving this CTLO in only four items (less than 10% of the submitted assessment items). This indicates a paucity of assessment items providing opportunities for students to develop teamwork skills, and to provide evidence of their growth and achievement. By contrast, 30 of the items addressed and demonstrated CTLO4.1 and 22 of those awarded credit for demonstrating this learning outcome. This shows that communication skills are more frequently addressed; however, there is still a need to ensure that students are given opportunities to communicate in a variety of contexts, including to non-scientific audiences. Figure 3 summarises this data.

Figure 3. Number of submitted tasks (from a total of 45) that achieved each assessment rating for CTLO3.5 and 4.1.



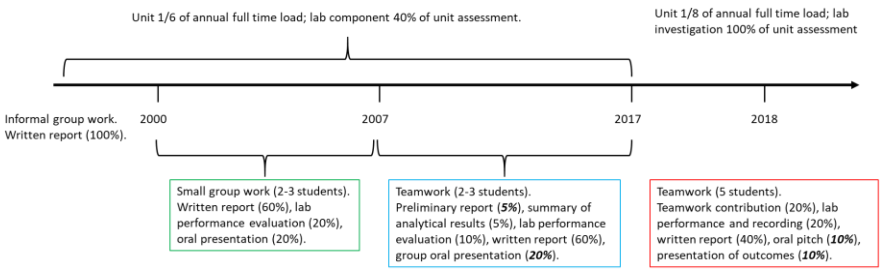
The full analysis of all 45 submitted tasks is presented in the project website at http://chemnet.edu.au/assessment. Selected exemplars from those tasks are also available for adoption, including the three case studies below. All rubrics used in the assessment of the exemplars are available on the website for adoption.

Case study 1. Team-based analytical laboratory project

The development of assessment of teamwork and communications skills within a third (final) year unit at an Australian university exemplifies the changed emphasis on these transferable skills in degree programs over the years. This unit, currently named Chemical Analysis and Inference, constitutes one eighth of an annual full time load. In this semester-long unit, teams of students plan, execute and report on an investigation of a complex authentic industrial "waste" material (solid or liquid or combination) including background research into the nature of their sample and possible contaminants, and state regulations of disposal options.

Within this laboratory investigation format, the emphasis on the development of effective teamwork skills and communication skills has increased with successive iterations of unit development. Figure 4 provides a timeline showing the changes to the structure of the assessment of the laboratory component over the past 20 years. This chart illustrates an increase in the weight and guidance being given to the team-work and communication aspects of the task. In addition, it shows the change from students working in informal groups in the laboratory prior to 2007 to students carrying out the laboratory investigations as collaborative teamwork. Staff focus on assessment of the success of teamwork developed in parallel with the change in student focus on working with their peers. Such a timeline is not unusual for the development of larger assessment items, where the actual experiments performed do not change but emphases change over time.

Figure 4. Timeline of assessment of chemical analysis laboratory component showing changes to structure and assessment. Percentages shown in bold italics are team assessment components.



Explicit assessment of individual effectiveness within teamwork was introduced from 2007 within the laboratory performance evaluation according to the criteria listed in Table 2.

Table 2. Checklist to scaffold student awareness of the assessment of their teamwork

Lab Performance Your demonstrators [teaching assistants] will assess your laboratory performance each week. This will involve observation of your activities during the laboratory: • Are you actively involved in experimental work and discussion within your group? • Are you prepared (do you have a clear idea of what you were planning to do? Did you have your risk assessment prepared at the start of the practical time)? Your prac. record book will be checked each week and initialed by a member of staff. The completeness of your record keeping will also be assessed. • Your involvement in the eLearning discussion group for your sample.

From 2007 onwards the students in this unit were carrying out the laboratory investigation as a collaborative team with common goals and shared outcomes (Johnson et al. 1991). The laboratory assessment included both a teamwork component (Table 2) and a team communication (presentation) component, both assessed by teaching assistants and academic staff.

The revision of this unit for 2018 arose when final year units changed weight to one eighth of a full-time annual study load. The laboratory project now constitutes the whole of the unit. Although the main components of student activity involve the research and investigation as before, team size and assessment of teamwork and of different forms of communication have been changed. These changes were implemented as a direct result of the concurrent involvement of one academic staff member in developing the tool of the Assessing the Assessment project. This resulted in much increased awareness of the importance of assessing transferable skills.

Team size was increased to five students to provide students with experience of a larger team with a greater diversity of team members, where each finds their own strengths to contribute. Teams now have more time for research, planning and undertaking the chemical analyses. Supporting students in their teams was one of the more important tasks of the teaching team, due to awareness of student issues with teamwork (Wolfe & Powell 2014). A scaffolded in-class discussion introducing teamwork was held when the teams were formed. This included a brief introduction of Belbin roles type categorisation for team members' self-evaluation (Aritzeta, Swailes, & Senior 2007; Belbin Associates 2018; Meslec & Curşeu 2015; van Dierendonck & Groen 2011), use of SWOT analysis (strengths, weaknesses, opportunities and threats) along with brief discussion of valuable materials found online (Crebert et al. 2011; OpenLearn 2018). The teams also discussed and revised the rubric to be used for peer assessment of teamwork contribution, based on rubrics developed within the institution and the literature (Dijkstra, Latijnhouwers, Norbart, & Tio 2016; Gabelica, Van den Bossche, De Maeyer, Segers, & Gijselaers 2014; Koh, Hong, & Seah 2014; Spatar, Penna, Mills, Kutija, & Cooke 2015). The rubric used is provided in Table 3 to indicate the highest and lowest standards for each criteria, because it is straightforward to infer the levels in between these.

Table 3. Criteria used in the assessment rubric applied for self- and peer-assessment of teamwork contribution; only the highest and lowest standards are provided for brevity.

Category	**Excellent 100-85%**	**Unsatisfactory 50-0%**
Intellectual Contribution	Contributes scientifically sound ideas and uses wide knowledge of appropriate scientific (chemical) concepts. Initiates possible directions for investigations. Can incorporate and add to others' suggestions. Contributes original and creative ideas for project development.	Contributes few scientifically sound ideas. Has scarce valid chemical knowledge to apply. Does not follow up possible directions for investigations. Has little input to project development.
Workload	Does a full share of the work; demonstrates initiative. Is aware of others' parts in project, assists others willingly without dominating.	Does less work than others. Doesn't get caught up in project after absence; doesn't offer or ask for help.
Getting Organized	Shows leadership in communication and planning / organization of team. Completes individual responsibilities and shares with team on time. Attends meetings punctually.	Makes little planning contribution. Does not complete some individual responsibilities and contributions are sometime late or compromise quality. Misses some meetings, no reason.
Communication among members	Always communicates punctually, openly, clearly and effectively.	Rarely communicates punctually, openly, clearly and effectively.
Participation in Discussions	Can lead discussions, draws out others' contributions. Participates willingly and inspires others. Helps discussion to move forwards.	Seems bored with conversations about the project; rarely speaks up and ideas are sometimes off the mark.

Supporting a constructive team climate	Treats all team members respectfully, keeps a positive attitude about the team and the project, motivating and encouraging other team members. Values others' contributions. Accepts help. Identifies possible issues and conflicts and helps in team resolution.	Does not act to support team morale or progress. Engages in non-committal or negative behaviours. May pursue own tangent and partly disengage.
Providing and Receiving Feedback	Habitually provides helpful, clear, and respectful feedback. Accepts feedback and responds to act on it constructively.	Often has little or no feedback to give or feedback is given rudely. Sometimes refuses to listen to feedback or does not act on it.

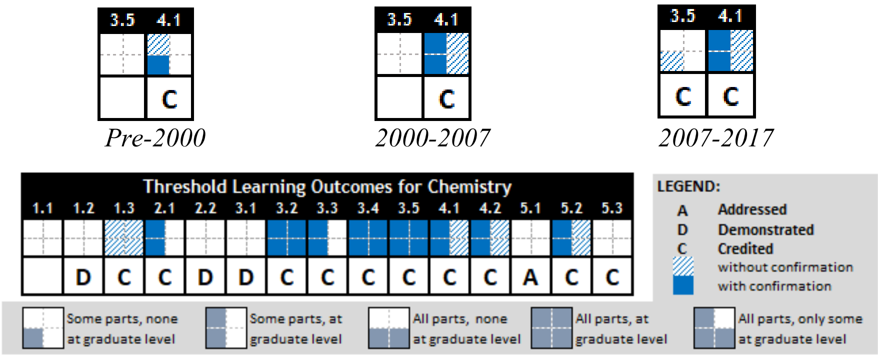
The assessment of teamwork was carried out using four measures as follows:

- students wrote two reflective pieces about their experiences, one in week 3 concerning prior teamwork experiences and one in week 13 (final week of semester) concerning teamwork experiences in this unit;
- staff provided an assessment of student contribution to an online wiki within the learning management system; and
- peer and self-evaluation of individual contribution to teamwork was made using the rubric in Table 3. This assessment was carried out at the end of semester following submission of all other assessment items. Because each student is peer assessed by four other team members, averaged peer assessments are less prone to potential bias, which can occur in smaller groups. Peer assessments were anonymous to the students, because they saw only the resultant mark, but not to the staff. A potential limitation of the use of this assessment protocol is that it was carried out at a late time point, and recall of contributions may not have been accurate.

These four measures contributed equally to the overall teamwork assessment, which makes up 20% of the final mark. Student informal feedback on the unit, and especially for the teamwork support and assessment, has been overwhelmingly positive.

Application of the evaluation tool to the different modes of assessment for this laboratory experience over time illustrates how the modifications to assessment protocols result in improved scores on the tool for both CTLO3.5 and 4.1. Figure 5 illustrates the outcomes from the tool for these CTLOs for the three earlier assessment modes, and for the full set of CTLOs for the current assessment mode. Note that these outcomes were obtained through evaluations of the assessment item by project team members.

Figure 5. Outcomes from the use of the evaluation tool on the assessments of the analytical laboratory project. Top: outcomes for previous assessment modes. Bottom: outcome for current assessment mode.



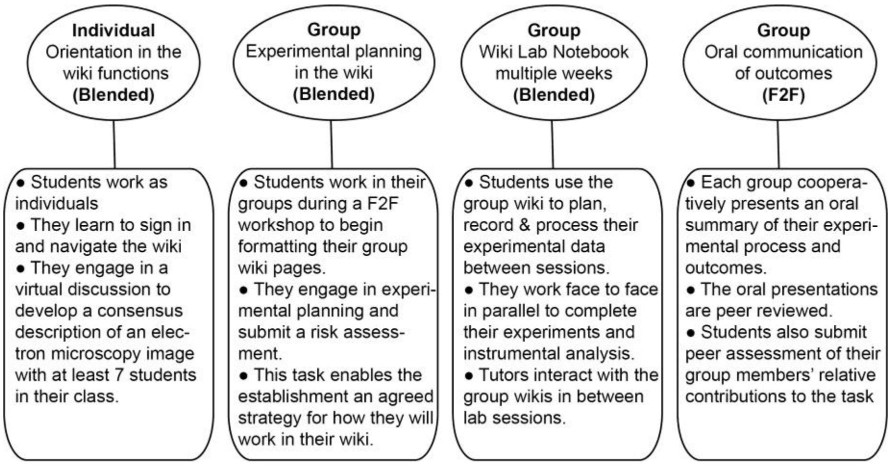
It can be seen that inclusion of assessed oral presentations and collaborative teamwork lead to higher scores using the tool for these CTLOs. In particular, the changes made for 2018 increased the score for CTLO3.5 from some parts, not at graduate level and without confirmation, to all parts at graduate level with confirmation.

Case Study 2. Supporting collaborative group work in a nanoscience course through a wiki-based laboratory notebook

The instructional design in this task intentionally aligned assessment of the intended learning outcomes with the learning activities and these were optimised prior to the development of the evaluation tool (Lawrie & Grøndahl 2015; Lawrie, Grøndahl, Boman, & Andrews 2016). This case study therefore illustrates an application of the tool to evidence key features of the assessment and how they align with CTLOs 3.5 and 4.1.

The original instructional design aimed to facilitate and evidence the collaborative interactions between individual students using a digital platform (wiki) as they progressed through a multi-week extended experimental investigation. Students worked in groups of three or four and were required to complete all their record-keeping during the stages of the experimental process and communication of their outcomes within their dedicated group wiki. Scaffolding (Figure 6) was introduced to develop students' skills and set expectations for their individual contributions to the group's wiki. The artefacts of this process were formally evaluated along with the effectiveness of different elements the task in supporting student learning (Lawrie et al. 2016).

Figure 6. Scaffolding embedded in the task across several weeks to support student engagement and success in the use of a wiki platform for collaboration and communication during the semester. (Blended = combination of online and face-to-face; F2F = face-to-face).



Student activity and achievement in each scaffolded activity was formally assessed. The laboratory component was weighted at 30% of the unit (which is one eighth of an annual full-time load), comprised of 20% for the wiki lab notebook and 10% for an oral presentation. To moderate the wiki lab notebook mark, individual students' peer assessment of their group members was applied and students completed these anonymously at the end of the laboratory task - their marks were only shared with instructors. The highest and lowest standards applied in the peer assessment criteria provided to students are shown in Table 4. There are many similarities to the assessment criteria provided in Table 3, illustrating essential aspects of individual contributions to group work that are applicable in many contexts. However comparison of these two tables also demonstrates the degrees of granularity or elements that can be made explicit in the criteria that evaluate individual students' contributions to collaborative work.

Table 4: Criteria used in the assessment rubric applied for peer-assessment to measure individual contribution to group activities; only the highest and lowest standards are provided for brevity.

Category	Excellent 100-85%	Unsatisfactory 50-0%
Collaboration	Participated beyond the expectations of the task. Showed leadership in setting & meeting goals; maintained group cohesion; and encouraging the best from team members. Showed leadership in the preparation of the elab report.	Participated minimally. Showed little concern for goals. Observed but didn't participate in goal setting. Completed assigned tasks late or not at all. Made no contribution to the elab report.

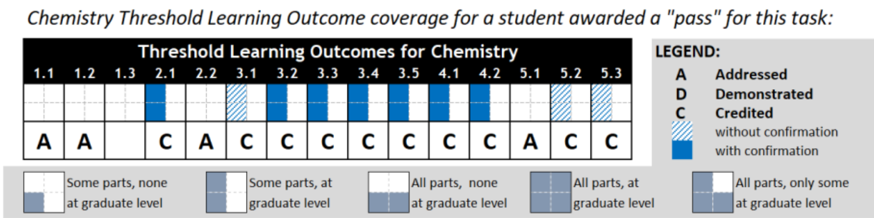
Intellectual Contribution	Provided an outstanding contribution to the design of experiments, analysis of data and interpretation of results. Demonstrated a deep understanding of the processes.	Limited participation in the design of experiments. Did not contribute to analysis of data and interpretation of results. Did not grasp the experimental procedures.
Communication	Established and promoted communication networks. Encouraged all group members to share their ideas and complete experiments. Listened attentively to others and proactively addressed other people's feelings and ideas.	Did not share ideas. Did not contribute to discussions. Did not show consideration for others.

It is important to emphasise that this task represented a blended learning and assessment environment where students collaborated face-to-face during their experimental work in the laboratory sessions as well as asynchronously in the wiki between lab sessions. Many groups also chose to discuss and formulate their wiki entries in the laboratory prior to independent editing. There was strong evidence that this platform had supported their development of effective cooperative and teamwork skills (Lawrie et al. 2016).

The communication skills assessed in this unit involve the asynchronous discourse in the wiki, the laboratory records, a written discussion of results and an oral presentation. The audience includes their peers, tutors, instructors and instrument scientists. The assessment criteria for the oral presentations include structure, content, design, delivery and professionalism.

This task has been implemented effectively annually since 2010 with minor adjustments based on student feedback. The outcomes of the use of the tool to evaluate this task are shown in Figure 7. Seven CTLOs have been confirmed as being assessed to graduate level (in part) through completion of this task. Hence the evaluation tool has validated the outcomes of the original instructional design that had targeted learning outcomes described in CTLO3.5 and CTLO4.1, confirming its utility.

Figure 7. Outcomes of the use of the evaluation tool for the laboratory assessment in nanoscience.



Case Study 3. Meta-assessment

The meta-assessment forms 20% of the assessment in a capstone research methods unit, which is core to the chemistry major and comprises one quarter of an annual full time load. The assessment has been undertaken every year since 2010, with only minor alterations. The three aims to this assessment task are for students to:

- critically evaluate their learning experiences by building a portfolio of assessment tasks from other courses they have studied as part of their undergraduate degree;
- define the outcomes of their assessments within the intended learning outcomes for each course as defined in curricular materials; and,
- align the work and the intended learning outcomes to a CTLO to chart its attainment through the lens of their experiences.

To achieve these goals requires students to meaningfully engage with education research literature on instruction and assessment design, most notably constructive alignment (Biggs 1999), which outlines a process for co-construction of meaningful assessment (Biggs & Tang 2007). There are two components within this assessment task:

- an individual reflective journal outlining the student's perspective of intended constructs developed as part of a series of workshops on reflective practice and research on chemistry education;
- a team-based showcase portfolio with embedded artefacts from their prior learning that demonstrate constructive alignment between intended and achieved learning outcomes.

In the individual reflective journals (Boud 2001), students engage in critical reflection (Mezirow 1990) and reflexive practice (Bolton 1999) to draw on their experiences. To assist this process, students appraise theories on teaching and learning of chemistry developed as part of a series of workshops on learning outcomes and constructive alignment; affective domain and sociocultural influences on learning; unique challenges when learning chemistry; and, assessment and evaluation. Students compare methods of research used to evaluate their efficacy in developing conceptual understanding by completing a survey with each workshop that gives them insight into their own perception or skills and develops their understanding of the intended constructs. Students are provided a choice of critical reflection frameworks through supporting materials (Bennett & Evans 2018).

The showcase portfolio asks students to work in teams of four to explore one of five categories from the CTLO statement, with the outcomes relating to chemistry content knowledge (CTLO2.1) explicitly not allocated. The electronic portfolio is used as a tool for asynchronous team development of the task (Reeves 2000), which allows for learner engagement in the task (Barrett 2007). The question posed to students in this portfolio task is: "do you as soon-to-graduate chemists have the evidence to demonstrate your achievement of these outcomes?" The group prepares a showcase of their assessment artefacts, and for each piece of work the group must explain: how the work addresses the intended learning outcome; what their perception of this work was at the time; how their perception has changed now; and, how they will take this achievement on to the next phase of their career (either to further study or into the workforce).

The assessment of this task is undertaken in two parts, worth 5% of the final grade and 15% of the final grade, respectively. First, the entries in the reflective journal are assessed once using a teacher-developed rubric, with criteria including intention, knowledge acquisition, reflection, and impact. Second, the students complete the constructive alignment process as part of the showcase portfolio by developing their own assessment rubric. This rubric is used by students to self-assess their performance, and then used by the teaching staff to do the same. Each self- and teacher-assessment is worth 5% of their grade. The final 5% of the grade comes from anonymous self- and peer-assessment of their teamwork using the Comprehensive Assessment of Team Member Effectiveness rubric (Loughry, Ohland, & Moore 2007) and system (Ohland et al. 2013).

The primary objective for the assessment of this task was to address two critical, but underrepresented CTLOs in the curriculum. First, to evaluate students' teamwork on co-construction of a task (CTLO3.5) and second, to explicitly evaluate their ability to self-direct their learning and assessment (CTLO5.1). However, the strength of the task is that the evidence collected in the process has the dual purpose of informing curricular developments at the home institution and assuring learning and providing evidence for attainment of every CTLOs. Paradoxically, due to the nature of the meta-assessment, the tool does not give any insight in this example because every CTLO is explicitly addressed.

Conclusions and implications for practice

The case studies described provide evidence to support the claim that this tool can be applied effectively in the process of instructional design to align assessment of learning outcomes with learning activities. Detailed examination of the evolution of the first example illustrates the typical iterative process of assessment improvement. These exemplars, along with others, are included in the searchable project website (http://chemnet.edu.au/assessment) and we anticipate adoption and adaptation as institutions seek ways to effectively assess transferable skills. In particular, we have shown that teamwork is rarely assessed in chemistry units at Australian institutions and we have provided a mechanism to allow academic staff to improve its coverage within their assessment tasks.

The tool has applicability across disciplines and to any set of intended learning outcomes that address benchmarking by institutions, professional bodies, and other accreditation committees. The tool is available for download from the website.

The experience gained from this project inherently developed expertise in the team and was transformational in itself, resulting in deep reflection on our own assessment tasks.

References

Aritzeta, A., Swailes, S., & Senior, B. (2007). Belbin's team role model: Development, validity and applications for team building. *Journal of Management Studies*, *44*, 96-118. doi:10.1111/j.1467-6486.2007.00666.x

Barrett, H. C. (2007). Researching electronic portfolios and learner engagement: The REFLECT Initiative. *Journal of Adolescent and Adult Literacy, 50*, 436-449. https://doi.org/10.1598/JAAL.50.6.2

Barrie, S. C. (2004). A research-based approach to generic graduate attributes policy. *Higher Education Research & Development, 23*, 261-275. https://doi.org/10.1080/0729436042000235391

Barrie, S. C., Hughes, C., Crisp, G., & Bennison, A. (2012). *Assessing and assuring Australian graduate learning outcomes: principles and practices within and across disciplines* https://ltr.edu.au/resources/SP10_1879_Barrie_Report%20_2013.pdf Accessed 31 Oct 2018.

Belbin Associates. (2018). The nine Belbin team roles. https://www.belbin.com/about/belbin-team-roles/ Accessed 28 Oct 2018.

Bennett, D., & Evans, C. (2018). Using critical reflection to get the most out of your learning. https://developingemployability.edu.au/tools/learning-experiences-critical-reflection/

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education, 32*, 347-364. https://doi.org/10.1007/BF00138871

Biggs, J. (1999). What the student does: teaching for enhanced learning. *Higher Education Research & Development, 18*, 57-75. https://doi.org/10.1080/0729436990180105

Biggs, J., & Tang, C. (2007). *Teaching for Quality Learning at University: What the Student Does* (3rd ed.). Maidenhead: SRHE and Open University Press.

Bodner, G. M. (2016). Introduction to plenary session. Greeley, CO: Biennial Conference on Chemical Education.

Bolton, G. (1999). Reflections through the looking-glass: the story of a course of writing as a reflexive practitioner. *Teaching in Higher Education, 4*, 193-212. https://doi.org/10.1080/1356251990040204

Boud, D. (2001). Using journal writing to enhance reflective practice. *New Directions for Adult and Continuing Education, 90*, 9-17. https://doi.org/10.1002/ace.16

Boud, D., & Falchikov, N. (2006). Aligning assessment with long-term learning. *Assessment & Evaluation in Higher Education, 31*, 399-413. https://doi.org/10.1080/02602930600679050

Committee on Professional Training. (2015). *Undergraduate Professional Education in Chemistry: ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs*. American Chemical Society. https://www.acs.org/content/dam/acsorg/about/governance/committees/training/2015-acs-guidelines-for-bachelors-degree-programs.pdf Accessed Oct 31 2018.

Confederation of British Industry. (2016). *The right combination: CBI/Pearon Education and Skills Survey*. http://www.cbi.org.uk/cbi-prod/assets/File/pdf/cbi-education-and-skills-survey2016.pdf Accessed Oct 31 2018.

Crebert, G., Patrick, C.-J., Cragnolini, V., Smith, C., Worsfold, K., & Webb, F. (2011). *Griffith Graduate Attributes Professional Skills Toolkit*. Brisbane: Griffith University.

de la Harpe, B., & David, C. (2012). Major influences on the teaching and assessment of graduate attributes. *Higher Education Research & Development, 31*, 493-510. https://doi.org/10.1080/07294360.2011.629361

Dijkstra, J., Latijnhouwers, M., Norbart, A., & Tio, R. A. (2016). Assessing the "I" in group work assessment: State of the art and recommendations for practice. *Medical Teacher*. https://doi.org/10.3109/0142159X.2016.1170796

Dunne, E., & Rawlins, M. (2000). Bridging the gap between industry and higher education: Training Academics to Promote Student Teamwork. *Innovations in Education and Training International, 37*, 361-371. https://doi.org/10.1080/135580000750052973

European Chemistry Thematic Network. (2016). *Chemistry Eurobachelor label: Guidelines for Applications* http://files.gandi.ws/gandi22757/file/1-eurobachelor_guidelines-1612.pdf Accessed Oct 31 2018.

Gabelica, C., Van den Bossche, P., De Maeyer, S., Segers, M., & Gijselaers, W. (2014). The effect of team feedback and guided reflexivity on team performance change. *Learning and Instruction, 34*, 86-96. https://doi.org/10.1016/j.learninstruc.2014.09.001

Gibbs, G., & Simpson, C. (2004). Conditions under which assessment supports students' learning. *Learning and Teaching in Higher Education, 2004-05*, 3-31.

Green, W., Hammer, S., & Star, C. (2009). Facing up to the challenge: why is it so hard to develop graduate attributes? *Higher Education Research & Development, 28*, 17-29. https://doi.org/10.1080/07294360802444339

Hager, P., Holland, S., & Beckett, D. (2002). *Enhancing the learning and employability of graduates: the role of generic skills*. https://www.bhert.com/publications/position-papers/B-HERTPositionPaper09.pdf Accessed Oct 31 2018.

Heckman, J. J., & Kautz, T. (2012). Hard evidence on soft skills. *Labour Economics, 19*, 451-464. https://doi.org/10.1016/j.labeco.2012.05.014

Hill, J., Walkington, H., & France, D. (2016). Graduate attributes: implications for higher education practice and policy. *Journal of Geography in Higher Education, 40*, 155-163. https://doi.org/10.1080/03098265.2016.1154932

Hughes, C., & Barrie, S. C. (2010). Influences on the assessment of graduate attributes in higher education. *Assessment & Evaluation in Higher Education, 35*, 325-334. https://doi.org/10.1080/02602930903221485

Johnson, D. W., & Johnson, R. T. (2009). An educational psychology success story: Social interdependence theory and cooperative learning. *Educational Researcher, 38*, 365-379. https://doi.org/10.3102/0013189X09339057

Johnson, D. W., Johnson, R. T., Ortiz, A. E., & Stanne, M. (1991). The impact of positive goal and resource interdependence on achievement, interaction, and attitudes. *The Journal of General Psychology, 118*, 341-347. https://doi.org/10.1080/00221309.1991.9917795

Jones, S. M., Yates, B. F., & Kelder, J.-A. (2011). *Science learning and teaching academic standards statement*. https://ltr.edu.au/resources/altc_standards_SCIENCE_240811_v3_0.pdf Accessed Oct 31 2018.

Knight, P. (2007). *Fostering and assessing 'wicked' competences* http://www.open.ac.uk/opencetl/sites/www.open.ac.uk.opencetl/files/files/ecms/web-content/Knight-(2007)-Fostering-and-assessing-wicked-competences.pdf Accessed Oct 31 2018.

Knight, P., & Page, A. (2007). *The assessment of 'wicked' competences* http://www.open.ac.uk/opencetl/sites/www.open.ac.uk.opencetl/files/files/ecms/web-content/knight-and-page-(2007)-The-assessment-of-wicked-competences.pdf Accessed Oct 31 2018.

Koh, E., Hong, H., & Seah, J. (2014). *An analytic frame and multi-method approach to measure teamwork competency*. Paper presented at the 14th International Conference on Advanced Learning Technologies.

Lawrie, G. A., & Grøndahl, L. (2015). Wiki technologies and communities: New approaches to assessing individual and collaborative learning in the chemistry laboratory. In J. García-

Martínez & E. Serrano-Torresgrosa (Eds.), *Chemistry Education: Best Practices, Opportunities and Trends* (pp. 671-691). Weinheim, Germany: Wiley-VCH Verlag GmbH & Co.

Lawrie, G. A., Grøndahl, L., Boman, S., & Andrews, T. (2016). Wiki laboratory notebooks: Supporting student learning in collaborative inquiry-based laboratory experiments. *Journal of Science Education and Technology, 25*, 394-409. https://doi.org/10.1007/s10956-016-9601-0

Lee, N., & Loton, D. J. (2015). *Capstone curriculum across disciplines: Synthesising theory, practice and policy to provide practical tools for curriculum design*. https://altf.org/wp-content/uploads/2016/08/Lee_N_NSTF_report_2015.pdf Accessed Oct 31 2018.

Loshbaugh, H. G., Laursen, S. L., & Thiry, H. (2011). Reactions to changing times: Trends and tensions in U.S. chemistry graduate education. *Journal of Chemical Education, 88*, 708-715. https://doi.org/10.1021/ed1008574

Loughry, M. L., Ohland, M. W., & Moore, D. D. (2007). Development of a theory-based assessment of team member effectiveness. *Educational and Psychological Measurement, 67*, 505-524. https://doi.org/10.1177/0013164406292085

Meslec, N., & Curşeu, P. L. (2015). Are balanced groups better? Belbin roles in collaborative learning groups. *Learning and Individual Differences, 39*, 81-88. doi:10.1016/j.lindif.2015.03.020

Mezirow, J. (1990). How critical reflection triggers transformative learning. In J. Mezirow (Ed.), *Fostering critical reflection in adulthood: a guide to transformative and emancipatory learning*. San Francisco, CA: Jossey-Bass.

Ohland, M. W., Loughry, M. L., Woehr, D. J., Bullard, L. G., Felder, R. M., & Finelle, C. J. (2013). The omprehensive assessment of team member effectiveness: Development of a behaviorally anchored rating scale for self- and eer Evealuation. *Academy of Management Learning & Education, 11*, 609-630. https://doi.org/10.5465/amle.2010.0177

OpenLearn (Producer). (2018). Working in groups and teams. https://www.open.edu/openlearn/money-management/management/leadership-and-management/working-groups-and-teams/content-section-0?active-tab=description-tab Accessed Oct 26 2018.

Peat, M., Taylor, C. E., & Franklin, S. (2005). Re-engineering of undergraduate science curricula to emphasise development of lifelong learning skills. *Innovations in Education and Teaching International, 42*, 135-146.

Pyke, S., O'Brien, G., Yates, B., & Buntine, M. (2014). *Chemistry Academic Standards Statement - revised* http://chemnet.edu.au/sites/default/files/u39/CHEMISTRY_Academic_Standards_Accreditation_Trial.pdf Accessed Oct 31 2018.

Ramsden, P. (2003). *Learning to Teach in Higher Education* (2nd ed.). London: RoutledgeFalmer.

Reeves, T. C. (2000). Alternative assessment approaches for online learning environments in higher education. *Journal of Educational Computing Research, 23*, 101-111. https://doi.org/10.2190/GYMQ-78FA-WMTX-J06C

Robles, M. M. (2012). Executive perceptions of the top 10 soft skills needed in today's workplace. *Business Communication Quarterly, 75*, 453-465. https://doi.org/10.1177/1080569912460400

Sadler, D. R. (2015). Three in-course assessment reforms to improve higher education learning outcomes. *Assessment & Evaluation in Higher Education*. https://doi.org/10.1080/02602938.2015.1064858

Sarkar, M., Overton, T., Thompson, C., & Rayner, G. (2016). Graduate employability: Views of recent science graduates and employers. *International Journal of Innovation in Science and Mathematics Education, 24*, 31-48.

Schmid, S., Schultz, M., Priest, S. J., O'Brien, G., Pyke, S. M., Bridgeman, A., . . . Jamie, I. M. (2016). Assessing the Assessments: Development of a tool to evaluate assessment items in chemistry according to learning outcomes. In M. Schultz, S. Schmid, & T. Holme (Eds.), *Technology and Assessment Strategies for Improving Student Learning in Chemistry* (pp. 225-244). Washington DC: American Chemical Society.

Schultz, M., Mitchell Crow, J., & O'Brien, G. (2013). Outcomes of the Chemistry Discipline Network mapping exercises: Are the threshold earning outcomes met? *International Journal of Innovation in Science and Mathematics Education, 21*, 81-91.

Spatar, C., Penna, N., Mills, H., Kutija, V., & Cooke, M. (2015). A robust approach for mapping group marks to individual marks using peer assessment. *Assessment & Evaluation in Higher Education, 40*, 371-389. https://doi.org/10.1080/02602938.2014.917270

Spronken-Smith, R., McLean, A., Smith, N., Bond, C., Jenkins, M., Marshall, S., & Frielick, S. (2016). A toolkit to implement graduate attributes in geography curricula. *Journal of Geography in Higher Education, 40*, 254-266. https://doi.org/10.1080/03098265.2016.1140129

Su, Y. (2014). Self-directed, genuine graduate attributes: the person-based approach. *Higher Education Research & Development, 33*, 1208-1220. https://doi.org/10.1080/07294360.2014.911255

The University of Sydney. (2016). *2016-2020 Strategic Plan*. Sydney: https://sydney.edu.au/dam/intranet/documents/strategy-and-planning/strategic-plan-2016-20.pdf Accessed Oct 29 2018.

Towns, M. H. (2010). Developing earning objectives and assessment plans at a variety of institutions: Examples and case studies. *Journal of Chemical Education, 87*, 91-96.

van Dierendonck, D., & Groen, R. (2011). Belbin revisited: A multitrait–multimethod investigation of a team role instrument. *European Journal of Work and Organizational Psychology, 20*, 345-366. doi:10.1080/13594321003590580

Wiggins, G., & McTighe, J. (2005). *Understanding by Design* (2nd edition ed.). Alexandria, VA, USA: Association for Supervision and Curriculum Development.

Wolfe, J., & Powell, E. (2014, 13-15 Oct. 2014). *Strategies for dealing with slacker and underperforming teammates in class projects.* Paper presented at the 2014 IEEE International Professional Communication Conference (IPCC).