Chapter 17
Use of PebblePad to Develop Scaffolded Critical Reflection in Scientific Practice

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Abstract This chapter will discuss the implementation of a suite of PebblePad activities and assessment tasks across the Bachelor of Science Advanced (Honours) undergraduate degree program. Enrolled in this program are students who scored in the top 11 percentile of all university entrants and are intentionally on a scientific research career trajectory. In preparation for the embedded honour component of the program, students undertake three core research project courses across the second and third academic year levels, each designed to develop an array of different research capabilities within a student's specific discipline. In these courses, students complete many traditional communication methods practiced by scientists. In the past, there has been limited focus on a key component of scientific process, the contextual reflection on the undertaking of scientific research. The PebblePad platform is a flexible tool that provides an opportunity to augment the existing research experiences through the development of scaffolded critical reflection of scientific practices holistically. This chapter will present the application of best practices associated with both blended design and undergraduate research experiences. It will explore the benefits of this combination and how to successfully enhance a critical component of developing the next generation of scientists using best practice blended learning design strategies.

Keywords Undergraduate research · Reflective writing · PebblePad · Critical evaluation

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17.1 Introduction

17.1.1 Experiential Learning

Experiential and inquiry-based learning theories offer a demonstrated rationalisation of science learning methodology. They are traditionally associated with positive student engagement and excellent learning outcomes. They encapsulate the notion of learning by observational or evaluative inquiry followed by practical evaluation and active exploration of concepts, consolidated by reflection and review based on the understandings described by Kolb (2014) of Lewin, Dewey and Piaget's theorems. Together they provide an excellent explanation for the nature of undertaking scientific research and understanding the nature of doing science whereby knowledge acquired through active experiences can be transformative (Mezirow, 2000). Core to implementation is the provision of inductive development of complex knowledge schema from concrete experiences and whole-task integration, along with collated supportive information that provides familiarisation and diminishing progressive scaffold. These form the crux of the four-component instructional design (4C/ID) model for complex learning (Van Merriënboer & Kirschner, 2017) that focuses on learning tasks, supportive information, procedural information and part-task practice. Without these, compartmentalisation, fragmentation and transfer paradox collectively result in inappropriate design and implementation with poorer, undesirable impacts and learning outcomes for students (Kirschner, Sweller, & Clark, 2006).

When considering experiential learning in undergraduate research experiences (URE), two core frameworks have relevance in understanding best practice implementation. These apply the models of engaged learning and teaching (MELT) principles and can be explored using the Researcher Skill Development (RSD) and Work Skill Development (WSD) conceptual frameworks (Willison, 2012; Willison & O'Regan, 2007, 2015; Wisker, 2017). These frameworks provide comprehensive articulation of the various facts of research considered to be core competencies to be developed. They also include an explicit and incremental development of associated ideal levels of autonomy in a research context.

Recommendations for students to engage with active learning that are both inquiry-based and experiential in nature are profuse (Bonwell & Eison, 1991; Kirschner & Van Merrienboer, 2008; Kolb & Kolb, 2005; Kolb, 2014; Mezirow, 2000; Van Merriënboer & Kirschner, 2017). These calls are particularly relevant within the undergraduate research space and specifically the science, technology, engineering and mathematics (STEM) discipline, the combination of which this chapter will focus on.

17.1.2 Undergraduate Research Experiences

There is a collective body of works advocating the inclusion of undergraduate research experiences and the benefits thereof (Brew, 2010; Kuh, 2008; National Academies of Sciences, 2017; Russell, Hancock, & McCullough, 2007; Zhang & Swaid, 2017) to become core business in developing the next generation of critical thinkers and specifically research scientists. Moreover, UREs are readily acknowledged to be a key high-impact educational practice for engaging students (Kuh, 2008). They combine the fundamentals of transformative experiences through experiential inquiry-based learning providing inspiration for subsequent exploration along with developing both technical capabilities and desirable graduate attributes.

Creating opportunities for students to become active stakeholders in research communities has been demonstrated to provide a beneficial shift in research culture (Healey & Jenkins, 2009) leading to higher levels of engagement and further pursuit of research careers as positive outcomes. In addition, the provision of core threshold learning outcomes for STEM graduates provides clear articulation of the nature of the capabilities required (Jones & Yates, 2011) including discipline knowledge and skills, along with diverse communication methodologies and professional responsibilities. Yet we know that the disciplinary culture of STEM focus tends to emphasis higher-order learning in preference to deep approaches with a distinct lack of reflective practices (Laird, Shoup, Kuh, & Schwarz, 2008) despite advocation for the incorporation of critical reflective practices (Auchincloss et al., 2014; Brew, 2013; Mathieson, 2016). Therein exists both a gap and an opportunity to develop these skills in undergraduate research students.

When designing UREs, several key factors contribute to successful outcomes. These include making research accessible and incorporating peer learning wherever possible (Overton & Johnson, 2016). In addition, authentic ways of experiencing and communicating the nature of science (Linn, Palmer, Baranger, Gerard, & Stone, 2015) is vital, as too is making thinking processes visible to undergraduate researchers (Brownell & Kloser, 2015). Developing UREs that meet both program and institutional goals whilst enhancing student experiences and future aspirations is core to a successful implementation (National Academies of Sciences, 2017).

17.1.3 Blended Learning Within UREs

Coupled with the desirable inclusion of UREs within the sciences comes a modern expectation that learning experiences also incorporate progressively more blended dimensions wherever appropriate. This blending could follow activity-level, course-level, program-level or institutional-level models, and the rationale for inclusion at core should demonstrate a move away from transmissive learning to active and interactive modalities (Bonk & Graham, 2012). Furthermore, blending has the potential to be enabling, enhancing and transformative (Bonk & Graham, 2012). Fundamentally, its inclusion should be underpinned by improved pedagogical strategies, along with being cost effective to increase access, flexibility and student learning outcomes.

The implementation of best practices in blended design requires several key considerations to be incorporated, and, whilst helpful, there is also the need to be mindful of potential challenges associated with realising a blended design. The strategy should support increased student competencies through authentic activities yet remain simple to undertake. Pedagogical approaches should ensure an active learning climate is maintained. The successful application of technology will depend on the experience of both developers and users, lead time to implementation and the availability of informative procedural information. When used in an education context, assessment strategies should also be authentic, flexible, developmental and iterative to promote deep learning (Overton & Johnson, 2016). Finally, implementation of a well-designed blended learning experience can still have unexpected outcomes if insufficient readiness for implementing these exists either in the institution (such as policy) (Adekola, Dale, & Gardiner, 2017), with teaching staff (experience and support) (Oakley, 2016) or with students (Tang & Chaw, 2013). Broad application along with prior experience should be complemented with training resources (Means, Toyama, Murphy, & Baki, 2013), along with financial and personal support mechanisms (Gregory & Lodge, 2015). Optimally, the designs most likely to enhance student learning outcomes would feature all these key considerations. Without careful attention they risk becoming key challenges (Alammary, Sheard, & Carbone, 2014; Boelens, De Wever, & Voet, 2017).

Missing from the discussion around undergraduate research is evidence of critical reflective practices by STEM students. The use of reflective practice is a mechanism known to assist in the process of making meaning and connection (Arthur & Bena, 2008; Eynon, Gambino, & Torok, 2014). The RSD framework lists it as a core facet of research competencies (Willison & O'Regan, 2015), and, moreover, we have long known that enhancement of scientific practices is supported by active reflective practice (Mezirow, 1997, 2000; Baird, Fensham, Gunstone, & White, 1991). Positive complex learning outcomes incorporate discipline capabilities, personal attributes and transferable skills, in conjunction with facilitating more visible learning and achievement progression, could all be evidenced by incorporating reflective practices into UREs. Yet for the most part, there is limited literature associated with the development of undergraduate capabilities in this area. Perhaps it is because the very nature of doing science can be considered critical reflective practice (Mathieson, 2016). Here, we propose two forms of reflection, both important in developing the future scientist: science as reflection, being the actual undertaking of experimental research processes to answer questions, and reflection as science, being the critique of higher-order thinking processes about the doing of science in a broader context. Recently, the use of e-portfolio development to complement summer undergraduate research student experiences (Weber & Myrick, 2018) reported an early example of the incorporation of both types of critical reflection in the STEM disciplines. It also evidenced growth-promoting experiences for the students that enhance the experiential learning space (Kolb & Kolb, 2005).

This chapter demonstrates the potential to design blended progressive undergraduate research experiences that both follows recommended best practices and addresses identified design challenges. It discusses the use of flexible digital technology, PebblePad. PebblePad is a digital personal learning space that can be utilised for the curation of artefacts associated with various experiences. In this chapter, we discuss its application to augment traditional scientific communication modalities with gathered evidence and developmental reflective practice that enables integration and development of research scientist identity.

17.2 Bachelor of Science Advanced (Honours) Program Context

The Bachelor of Science Advanced (Honours) degree program is a 4-year undergraduate degree program offered by a large government-funded institute in Australia, Griffith University. Students can enrol into the program on one of two discrete campus locations, being Brisbane and the Gold Coast. The program attracts academically high achieving students who are intentionally on a scientific research career trajectory. The program offers majors in applied mathematics, biochemistry and molecular biology, chemistry, clinical sciences, geography, marine biology, microbiology, physics and wildlife biology.

The precept underpinning the design of these courses is that students already on a research scientist career track can engage early, and in an individual manner, with the ways of doing science. A key attraction for the program is the opportunity for students to undertake four discrete research courses throughout their undergraduate years. There are three courses combined that contribute 40 credit point (CP) of the total 240CP required to complete a standard bachelor's degree plus an 80CP research honours year. Students undertake two 10CP research courses consecutively in their second year and a further 20CP course across the whole of 3 years in preparation for honours. These experiences contribute to developing excellent research skills for students in the program and expanding both the breadth and scope of research projects. Together, these opportunities allow extension for capable students and enable better informed choices for their honours' project, having previously developed foundational knowledge in a research area(s) of interest. In addition, they assist in developing realistic expectations regarding a research science career track and aid in a rapid and successful transition into the honours' year.

17.3 Project Design

17.3.1 Design Rationale

This chapter will explore the holistic program assessment design developed during 2016–2017 to augment the existing research opportunities within the program. This design spans the three research courses undertaken in second and third years and was implemented for the level two courses for the 2017 cohort. They were also developed for the level three courses for implementation across 2018.

The nature of the research tasks can be highly variable and is individually developed, dependent on mentor availability, the nature of the discipline and a student's prior capabilities. For each of the courses, students undertake research activities under the mentorship of a researcher or research academic, ideally with a different mentor for each course. Mentor research facilities may be part of a specific research institute within the university, within individual researcher facilities or associated with industry partners and students. The nature of the tasks spans both theoretical and practical aspects, depending on the discipline. In addition, the courses ideally expedite the rate of progressive development of career researchers through the RSD framework stages reaching the boundary between supervisor instigated and researcher instigated inquiry during early undergraduate years (Willison & O'Regan, 2015).

Emerging scientists need opportunities to develop and demonstrate their high level of communication capabilities in many different formats, directed to different audiences and for different purposes. These include written descriptions of research such as a dissertation, journal article or public science presentation. It may also include oral communication to diverse audiences including other researchers in the field through to the general public.

Historically, assessment for these courses has offered these opportunities to students by requiring them to complete traditional scientific communication tasks that evaluate their capacity to articulate their theoretical or experimental research findings. These included dissertations, conference poster presentations and seminars. In addition, students were evaluated on their ability to conduct research in an independent, ethical manner appropriate to the level at which they were working.

With the introduction of the personal learning platform, PebblePad, came the opportunity to redevelop a component of the research course assessment strategies within the program. It created a prospect to undertake core aspects of what has been described (Alammary et al., 2014) as "high-impact blend", where existing courses were rebuilt from scratch (or close thereto). In curriculum development, both course and program learning outcomes were constructively aligned with assessment outcomes (Biggs, 1996). Whilst the core traditional assessment design had previously been implemented, minimal blended design or implementation strategies and support mechanisms had been incorporated. The introduction of agreed beneficial additional learning outcomes provided precept for the introduction of aligned assessment and the development of reflective practices to support graduate attributes for critical judgement regarding knowledge/skill, effective communicators and developing social responsibilities and engagement in the scientific community. Activities contributed to the enhancement of the traditional assessment regime, but now PebblePad has provided a simplified mechanism to implement this in a blended format.

The redesign also satisfies the criteria of the Science Threshold Learning Outcomes (TLOs) (Jones & Yates, 2011). The three research courses inherently provided the opportunity to demonstrate a coherent understanding of science underpinned by depth and breadth of scientific knowledge (TLOs 1 & 2). Experimental research tasks undertaken students also addressed TLO 3, developing inquiry and problem-solving skills. In early offerings of the courses, scientific communication methodology was limited to research reports, a poster and an oral presentation all directed to a knowledgeable scientific audience. TLO 4, personal and professional responsibility, was also encompassed by students undertaking independent, self-directed individual and team context projects within disciplinary and ethical constraints. The blending of each courses augmented TLO 1 by contextualising how scientists work, not just theoretically and experimentally, but holistically within a community. It also enhanced critical evaluation and synthesis of information from a range of sources including peers and future employers (TLO 3) that incorporated developing articulated reflective practices and value added to TLO 4 by including further modality of reflective writing for alternate audiences.

Active reflective practice is a key element of being an excellent scientist. The capability to review research activities, reflect on their outcomes and use the lessons learnt from these to shape the direction of future research activities is a central element of scientific practices. Yet in undergraduate research opportunities, written skills often focus primarily on the communication of research outcomes without the embedding or developing reflective practice.

The ability to write critically in a reflective manner is important for progress but often receives less attention in undergraduate written assessment options. The blended redesign for this program provided the opportunity to scaffold and develop the reflective writing capabilities of undergraduate researchers across their program. As students' progress, each course develops a mixture of communication practices that will become core to how they communicate holistically in their career pathway.

17.3.2 Activities and Assessment Design

The scaffolded, integrated and progressive activities these emerging scientists undertake throughout their program develop many different aspects of their capabilities. A summary of the progression is described in Fig. 17.1.

17.3.3 Blended Learning Design

The introduction of a new course convenor in conjunction with a change in university strategic priority provided an opportunity to develop some aspects of the three course designs using the PebblePad platform. An applied design overview is described in Fig. 17.2. There were two teams of contributors for the design of the emerging scientist workbooks in PebblePad. The academic team included the program director, and course directors were supported by a faculty-level blended learning (BL) team. The design encompasses a preparatory stage creating resources, both student (workbook and worksheets) and academic facing (ATLAS management system). Student products were initially automatically submitted with activities completed progressively. These activities were variable, depending on the specific course students were undertaking. The workbooks had inbuilt self-assessment tools, grading rubrics and areas for specific and holistic feedback.

Research Task 1 The first opportunity to implement PebblePad was in the Research Task 1 course, worth ten credit points (see Fig. 17.1). This course included two traditional assessment items for students: an evaluation of the ability to conduct research independently at an appropriate level in an ethical manner, and a dissertation-type submission summarising their research processes and research outputs. Reflective writing formed a third assessment item for the course and was used initially as a learning resource on which subsequent courses build. In this first course, only formative assessment was attributed to the task (it was included as a hurdle to successful course completion).

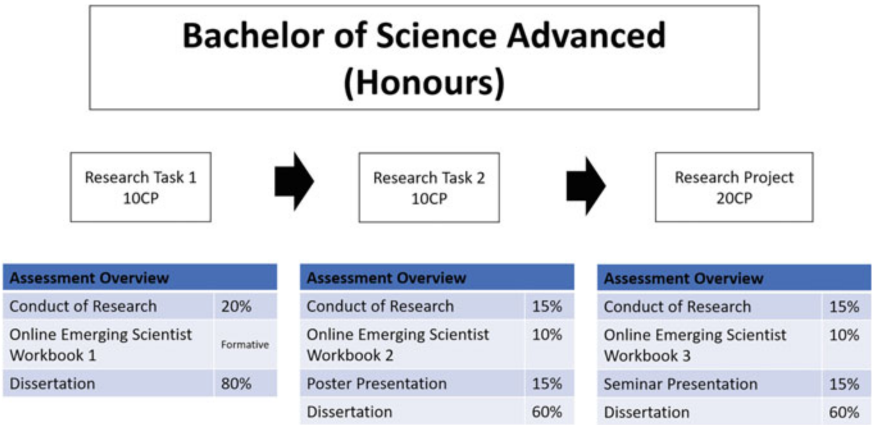


Fig. 17.1 Overview of the assessment design for the Bachelor of Science Advanced (Honours) research-based courses

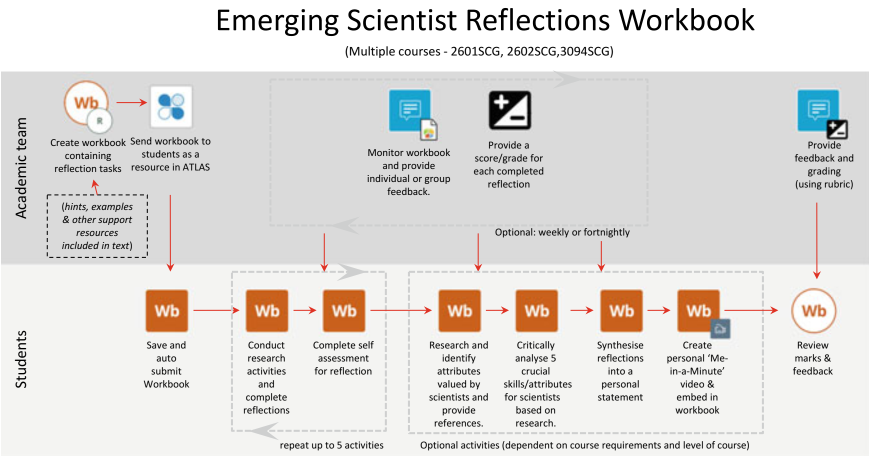


Fig. 17.2 Blended learning design of PebblePad for program approach

Supervisor Review of Conduct of Research (20%) The purpose of this assessment was to evaluate aspects of research conduct such as commitment and approach to work, independent working capacity, skills development and ethical conduct. Each subsequent course also had a similar assessment item.

Dissertation (80%) The writing of a traditionally formatted dissertation, or research report, that included a critical evaluation of prior research, aims and rationale along with details of work undertaken, analysis and interpretation of data and conclusions draw. This is the most common form of research evaluation used in undergraduate research, often referred to as the "laboratory report". Each subsequent course required students to submit a dissertation that should increase in complexity as writing capabilities develop.

Emerging Scientist Reflections Workbook 1 (0%) In this course, the purpose of the reflective task was to develop good reflective practices associated with doing research. Assessment was formative in nature, and students received feedback to develop their thinking process articulation. Students were provided with a scaffolded template, within the PebblePad platform that facilitated their reflections on activities undertaken associated with conducting research (see Fig. 17.3). Students were required to complete an Emerging Scientist Workbook 1 that contained five blank copies of the reflective template for discrete reflection on different aspects of the research they were undertaking. The intent of this task was to communicate to students the importance of undertaking reflective practices without detracting significantly from the traditional research outputs expected of scientists. Furthermore, the lack of grade meant students were able to slowly develop a writing style not traditionally encouraged, pursued or assessed in scientific degree programs.

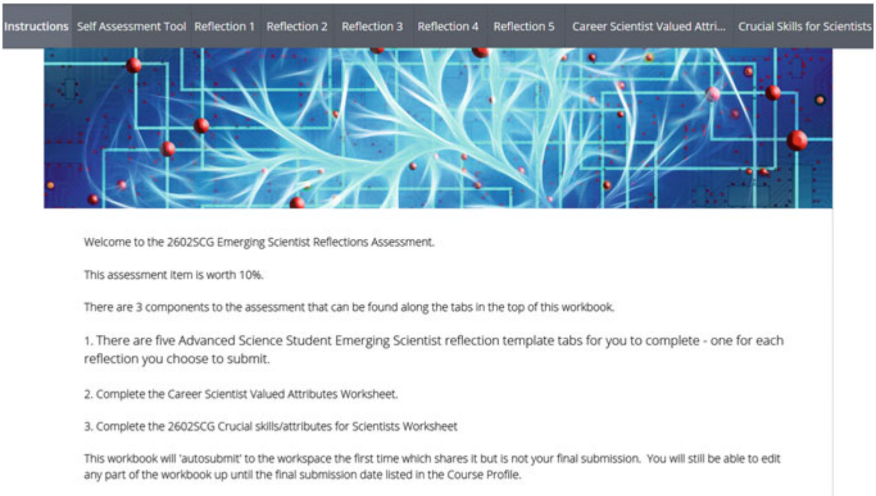


Fig. 17.3 Example of a PebblePad emerging scientist workbook

Research Task 2 The second research course was Research Task 2, worth ten credit points (see Fig. 17.1). This course included three traditional assessment items for students. Both the evaluation of the ability to conduct research independently at an appropriate level in an ethical manner and the dissertation submissions were as per the Research Task 1 course offering with an expectation that the demonstrated output levels were of a higher quality. These two items were weighted at 15% and 60%, respectively. In this course, two additional assessment items were incorporated to develop different communication capabilities.

Poster Presentation (15%) The display of research posters is a common method by which scientists succinctly present core findings, usually in a conference setting. It is a communication method that requires the ability to distil information appropriately and present it in an interesting and engaging manner that can be supported with oral explanation in either Pecha Kucha format or conversational dialogue. This assessment item enabled students to demonstrate their ability to be succinct in both written and oral forms.

Emerging Scientist Reflections Workbook 2 (10%) The second of the three reflective writing requirements within the program required the students to complete a scaffolded workbook that built on their reflective processes developed the previous semester. Students were again required to complete five reflections using the same template as in Research Task 1 course. In addition, there were two further tasks to extend their reflective practices.

The first was the identification of valued attributes career scientists require. Students were encouraged to seek evidence of the types of skills required by researchers from multiple sources such as practising scientists, job advertisements, position descriptions for major companies, research papers or news articles that include data and reports or scientific resumes.

Students were then required to critically reflect and prioritise key capabilities they have identified from each of the sources. They then provided a critique of their own experiences and capabilities to ascertain whether they were developing the appropriate skill sets or have areas they could focus on in the future and how these align with the skill sets identified in the second workbook task.

Research Project The third research course was a research project, a 20-credit point course taken either over a single or dual trimester (see Fig. 17.1). As with the previous two courses, student ability to conduct research and the submission of a dissertation were required assessment items. Weighting of these two items was as per the Research Task 2 course, being 15 and 60%, respectively. In this course, two additional assessment items were incorporated to develop different communication capabilities.

Oral Presentation (15%) Scientists regularly communicate their findings in several different oral platforms. For this task, students were required to present their project findings in a form like those used in conference seminar presentations, where the audience is familiar with, though not necessarily expert in, the field. As with the poster presentation, this required students to demonstrate oral communication skills in a more detailed and scientific manner.

Emerging Scientist Reflections Workbook 3 (10%) Students were encouraged to continue the use of the previous template for regular reflective writing. In addition, students were required to complete three synopsis reflections for the categories of discipline skills, transferable skills and personal attributes. Here, the scaffolds used in previous templates were removed. Students then used their reflections from all three courses along with the critical understandings they developed in Research Task 2 to create a synopsis of their undergraduate research experiences to date. This promoted active critical reflection with forward facing outcomes. Students then created a "Me-in-a-Minute" video (Jorre de St Jorre, Johnston & O'Dea, 2017) based on this collection of information and how these connect to where the student perceives they would like to progress their research career.

17.3.4 Core Themes of the Blended Learning Design

The remainder of this chapter will explore the processes and outcomes associated specifically with the Emerging Scientist Reflections PebblePad workbook activities embedded into each of the three undergraduate courses. The completion of research aspects of this chapter was conducted in accordance with approved human ethics requirements as described in the introductory chapter.

Setting Expectations The reflective template was developed as a scaffolded, simple way to focus on key aspects of reflection on scientific work. In the first application, students use the template to focus on five different experiences they have had during their first research course. Progressively, simplified versions of the same template were then used for subsequent courses. The template used a series of prompt questions to stimulate critical reflections on different possibilities. The provision of opportunity to embed artefacts associated with reflections also provided a breadth of scope for the student activities. Here, detailed exemplars were not included to reduce potential breach of academic conduct through plagiarism.

Each of the three courses had a workbook created in PebblePad. The format allowed students to quickly identify the different tasks required for the assessment item. Each workbook had a welcome landing page providing instructions on how to use the workbook and what was required (see Fig. 17.4 for an example). For the two latter workbooks, there was also a self-assessment tool for students to check their standard of completion. The assessment marking rubrics were also provided within the PebblePad workbook, as well as on the course site and in the course profile document. Examples of a variety of rubrics used within the PebblePad platform can be found in Fig. 17.5.

The use of specific exemplars for more complex tasks, like critical reflection on personal skills developed, that are highly valued by research scientists also provided students with an idea of the writing style and types of descriptive explorations they could undertake. An example can be seen in Fig. 17.6.

For this workbook, students were also asked to use a simple likert scale to indicate how long the workbook took them to complete (Fig. 17.7). This initially sets expectations associated with the anticipated amount of time spent on the task. It then additionally provides feedback both to students themselves and to academic staff relating to time management and time-on-task relative to an assessment weighting.

Making Connections It has been noted (National Academies of Sciences, 2017) that sometimes the undertaking of high-level thinking activities could benefit from a little more signposting and explicit identification of the connections between knowledge, tasks, assessment and student learning outcomes. In addition the use of reflective practice, pedagogy helps students to “make meaning from specific learning experiences and connections to other experiences, within and beyond the course” (Eynon et al., 2014, p. 101) and that ultimately this will contribute to developing their graduate capabilities and employability. In each of these courses, the PebblePad platform

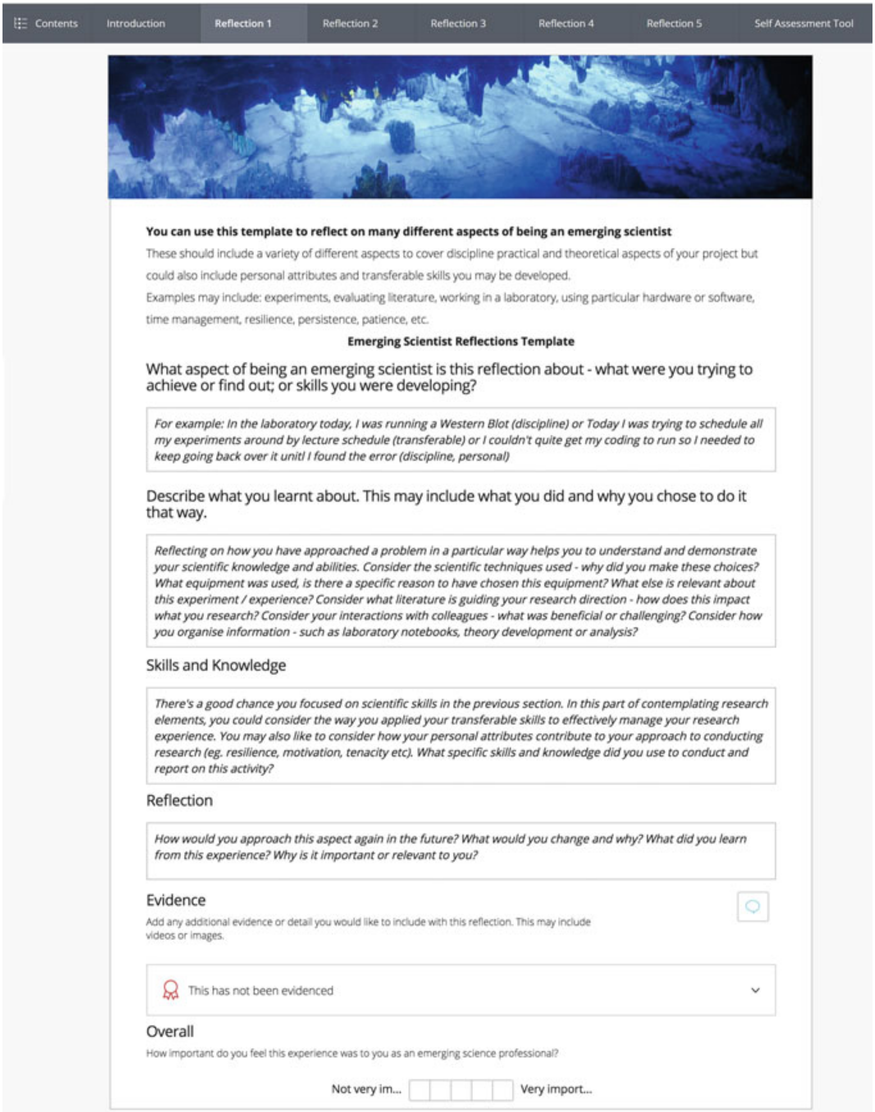


Fig. 17.4 Example of a scaffolded reflection including prompt questions from Research Task 1 course workbook

(a)

Emerging Scientist Personal Reflections (2%)

Follow the resource template in PebblePad to develop your reflections which should each include a description of the activity you were completing, discussion on what you did and why you chose that particular method, what skills and knowledge were involved in this element of your research, how you felt you went, what you learnt and its future relevance and implications for you.

Exemplar:

I completed a SDS-PAGE gel. The gel ran successfully, the banding pattern was appropriate and I was able to use the gel for a western blot. This is a standard method that can be further used with other experiments like western blotting to identify protein content in tissue extracts that I will need to know if I want to study Protein X expression in neurological tissues.

Use the rubric below to self assess how you think you went in this task. This is the same rubric that you will be graded with.

	Skilled	**Developing**	**Underdeveloped**
Description	All reflections include a critical evaluation description of the activity described, the skills and knowledge learnt and critical reflection on how future iterations may differ.	Some description of the activity described, the skills and knowledge learnt but lacking critical reflection.	Explanation of activity, purpose and implementation are minimal and without justification.
Reflection depth	All reflections include reference to both personal and professional impact of the activity.	Majority of reflections are limited to one domain (eg only emotional/personal or intellectual/professional) impact of the activity.	Skills and knowledge description is limited and lacks personal reflection on the activity.
Number of reflections submitted	Submitted 5 reflections.	Submitted 5 reflections.	Did not submit 5 reflections.

(b)

Career Scientist Attributes Identification (3%)

Use the worksheet resource template in PebblePad to collate the information you source regarding valued attributes for career scientists.
Use the rubric below to self assess how you think you went in this task. This is the same rubric that you will be graded with.

	Skilled	**Developing**	**Underdeveloped**
Multiple sources/types of sources of information were utilised	Multiple sources Multiple types of sources utilised	Multiple sources but of the same type	Not multiple sources Not multiple types of sources
Each source included a description of how they were credible and reliable	Detailed evaluation	Basic evaluation	No evaluation
A variety of specific skills/attributes were identified from source information	Multiple skills/attributes described	Only a couple of skills/attributes described	No variety of skills/attributes

Fig. 17.5 Example of variety of self-assessment tools. **a** Skill and complexity. **b** Source evaluation development. **c** Breadth of reflection and time-on-task

(c)

Use this template to Self Assess whether you have successfully completed your workbook.

Select which of the areas your individual reflections have tended to focus on. This will help you develop reflective breadth across the different aspects of emerging scientific work.

Please select the most appropriate box

	Reflection 1	Reflection 2	Reflection 3	Reflection 4	Reflection 5
Discipline knowledge/skills					
Transferable Skills					
Personal Attributes					
Other					

Fig. 17.5 (continued)

Critical Analysis and Alignment (5%)

For each of the five identified skill discuss how they are relevant to your future career as a scientist (0.5% for each skill) and how the project you have undertaken this trimester has developed your skills and capabilities or how you could develop them in the future (0.5% for each skill).

Exemplar 1 (Skill was developed): I identified that pipetting is an important skill for a molecular biologist as most experimental work is conducted at the micro volume scale. During this trimester I have improved my pipetting skills by completing a number of plasmid preparations where I successfully isolated DNA.

Exemplar 2 (Skill could be developed in the future): I identified that pipetting is an important skill for a molecular biologist as most experimental work is conducted at the micro volume scale. Unfortunately I didn't get to do very much pipetting as the experiments I undertook did not require micro volumes. However, pipetting is a skill that improves with practise so in the future I could undertake experiments that required more pipetting.

Both of these exemplars would receive satisfy the criteria equally.

If you like, you can use the box below to comment on whether you believe you have successfully fufiled the criteria for each skill.

Fig. 17.6 Exemplars for critical analysis

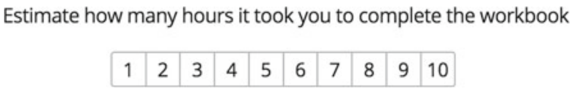


Fig. 17.7 Setting time frame expectations for task completion

Table 17.1 Development of connections through BL course design

Theoretical principles	↔	Practical applications
Undergraduate teaching laboratories	↔	Actual research laboratories
Undergraduate learning experiences	↔	Real-world learning experiences
Student thinking approach	↔	Scientific critical thinking
Current skill set (discipline, transferable and personal)	↔	Desirable skill set for future research endeavours
Student identity	↔	Emerging scientist identity
Experimentation	↔	Reflective practice

enabled simple yet effective ways to achieve these desirable attributes. The workbook templates helped to identify the importance of discipline knowledge, the development of transferable skills and personal attributes students had advanced during their research tasks. The alignment of formative tasks and assessment directly to learning outcomes is a key to any good learning design (Dunn & Mulvenon, 2009). However, the online format enabled not only simple correlations to the types of skills career researchers need to attain, they also provided a means by which students could utilise these materials readily for the compilation of evidence towards their own scientist capabilities and attributes. Furthermore, activities contributed to student development of professional identity associated with the way scientists undertake scientific research and how they themselves are developing these capabilities (Auchincloss et al., 2014; Brownell & Kloser, 2015).

The PebblePad tasks promoted making several different types of connections that are summarised in Table 17.1. Together these promoted broader thinking around what a scientist does, not just the undertaking of theoretically and practically based research activities alone.

Holistic Reflection and Consolidation In each course, there was the opportunity to reflect on the whole trimester experience. However, in the third research course, students built on all their previous experiences and what they had learnt about reflective practice, their own skills and capabilities and how these are relevant and applicable to their future career as a scientist. The workbook that they completed was a further modified version of the previous two. Students were encouraged to continue using reflective templates. However, the template had been simplified with much of the previous scaffolding, such as prompt questions and early exemplars, having been removed as students became more familiar and adept at critical reflective writing. In addition, they were asked to focus on three important aspects of their development as a research scientist being their discipline skills, transferable skills and personal attributes. These reflections demonstrated consolidation of what they had learnt over the previous 2 years and to demonstrate consideration for the impact these may have on their future career.

The final task was to capture these sentiments in a one-minute video presentation following the Deakin University Me-in-a-Minute (Jorre de St Jorre et al., 2017) presentation format. The video was a way of creating a succinct compilation of the student's key research capabilities, demonstration of their understanding of how these are important to their career pathway (Dickfos, Cameron, & Hodgson, 2014) and how they would be a suitable future higher research candidate or employee. The blended format meant that it could be used for presenting to potential honours research supervisors, or collaborators, or members of the broader public in the future. It also became a digital artefact that could be added to personalised e-portfolios or included in their LinkedIn profile.

This output provided an excellent accompaniment to the traditional research dissertation and seminar presentation. Together, these provided an overview of the student as a scientist which demonstrated not only their experimental research outcomes but also developing a balanced perspective on their broader communication capabilities.

17.3.5 Benefits of the Design Methodology

The Bachelor of Science Advanced (Honours) program research courses required the continued incorporation of highly valued traditional methods of research communication. However, the incorporation of BL through the implementation of PebblePad has value added to these traditional modalities and advanced both the reflective and critical thinking capabilities of students.

PebblePad offered the ability to incorporate several best practice measures for evolving and realising student learning outcomes with relative simplicity and limited experience or development time required.

Key benefits identified were:

- Development of communications skills for multiple audience types and delivery styles;
- Initial scaffolding and progressive simplification of resources to support the development of reflective writing capabilities. These include setting expectations, including self-evaluation, identification of time-on-task and self-reflection;
- Combination of progressive formative and summative assessment to support skill development;
- Consolidation and incorporation of prior experiences in holistic critical evaluation of student research capabilities;
- Opportunity for rapid and personalised feedback;
- Real-world contextualisation of research practices that enabled visibility of thinking.

The introduction of reflective writing to science undergraduates is an uncommon activity. The opportunity to develop this capability early in the first offering, as well as providing personalised feedback, but without academic weighting, is an excellent formative assessment methodology. The use of the same template in subsequent courses boosts students' confidence to complete tasks successfully and minimises the need to learn additional methodologies. The inclusion of PebblePad reflections also allows the research progress of students to be supported more effectively as students seem more likely to raise issues or concerns in this reflective format than to address them personally with supervisors.

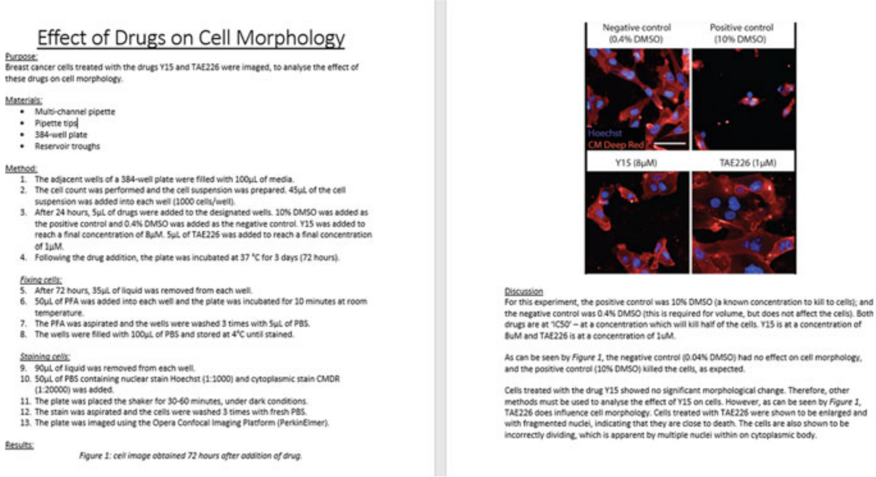
The iterative use of scaffolded templates enabled students to quickly determine important elements to focus their reflections on and minimise potential cognitive overload.

Simple measures can be introduced that facilitate self-assessment and feedback. The online format allows the incorporation of digital marking rubrics within the workbook. Whilst not in itself a novel concept, the inclusion in the same digital space as the assessment item was beneficial as it afforded opportunity for students to apply utilize it for progressive self-assessment (Dawson, 2017). The incorporation of a simple time spent rubric provided feedback to students regarding appropriate time-on-task but also feedback to developers. One of the key issues with the incorporation of BL into a course is the amount of extra time students might need to spend on activities (Alammary et al., 2014). Whilst this was an additional task compared with previous offerings, the time stamp helped confirm expectations. It also provided rapid feedback to developers that the amount of time students had spent on a task was not disproportionate to the task expectations, something that under different circumstances may take several iterations of an assessment item to feed back to academics.

Overall the program design within these three research-based courses was able to make explicit connections between research outputs, the ways of doing science and how these contribute to developing attributes desirable in a career researcher. This was in alignment with critical components for course-based undergraduate research experiences (Auchincloss et al., 2014; Brownell & Kloser, 2015). It also enabled students to identify desirable characteristics and to recognise these or determine the need for development of these early on. It is expected that these will support student outcomes as they pursue their quest to become scientists.

17.4 Implementation of the Design

The development of reflective practice that was critically aligned with the development of desirable career researcher attributes was varied and insightful. In-depth evaluation of student outputs is the subject of a separate article.



Effect of Drugs on Cell Morphology

Purpose:
Breast cancer cells treated with the drugs Y15 and TAE226 were imaged, to analyse the effect of these drugs on cell morphology.

Materials:
- Multi-channel pipette
- Pipette tips
- 384-well plate
- Reservoir troughs

Method:
1. The adjacent wells of a 384-well plate were filled with 100μL of media.
2. The cell count was performed and the cell suspension was prepared. 45μL of the cell suspension was added into each well (1000 cells/well).
3. After 24 hours, 5μL of drugs were added to the designated wells. 10% DMSO was added as the positive control and 0.4% DMSO was added as the negative control. Y15 was added to reach a final concentration of 8μM. 5μL of TAE226 was added to reach a final concentration of 1μM.
4. Following the drug addition, the plate was incubated at 37 °C for 3 days (72 hours).

Fixing cells:
5. After 72 hours, 35μL of liquid was removed from each well.
6. 50μL of PFA was added into each well and the plate was incubated for 10 minutes at room temperature.
7. The PFA was aspirated and the wells were washed 3 times with 5μL of PBS.
8. The wells were filled with 100μL of PBS and stored at 4°C until stained.

Staining cells:
9. 90μL of liquid was removed from each well.
10. 50μL of PBS containing nuclear stain Hoechst (1:1000) and cytoplasmic stain CMDR (1:20000) was added.
11. The plate was placed the shaker for 30-60 minutes, under dark conditions.
12. The stain was aspirated and the cells were washed 3 times with fresh PBS.
13. The plate was imaged using the Opera Confocal Imaging Platform (PerkinElmer).

Results:

Figure 1: cell image obtained 72 hours after addition of drug.

Discussion
For this experiment, the positive control was 10% DMSO (a known concentration to kill to cells); and the negative control was 0.4% DMSO (this is required for volume, but does not affect the cells). Both drugs are at 'IC50' – at a concentration which will kill half of the cells. Y15 is at a concentration of 8uM and TAE226 is at a concentration of 1uM.

As can be seen by *Figure 1*, the negative control (0.04% DMSO) had no effect on cell morphology, and the positive control (10% DMSO) killed the cells, as expected.

Cells treated with the drug Y15 showed no significant morphological change. Therefore, other methods must be used to analyse the effect of Y15 on cells. However, as can be seen by *Figure 1*, TAE226 does influence cell morphology. Cells treated with TAE226 were shown to be enlarged and with fragmented nuclei, indicating that they are close to death. The cells are also shown to be incorrectly dividing, which is apparent by multiple nuclei within on cytoplasmic body.

Fig. 17.8 Example of a student's evidencing of research associated activities within a Research Task 1 workbook

17.4.1 Student Completion of the BL Activities

This section discusses some of the ideas the design allowed students to express. The astute and personal critiques were refreshing to see, often far more in depth than required. The BL initiatives implemented for the degree program were able to capture previous unevidenced development student capabilities, and students used the design creatively for their own purpose.

Interestingly, students utilised the reflective template in surprising and unintended but positive ways. Some students also included experimental outcomes in their reflections along with quickly capturing their thoughts regarding those outcomes. Included with this was dialogue regarding the pros and cons, thus articulating some excellent examples of learning by failure and reflection for subsequent future improved implementation. Further to these inclusions, some students also took the opportunity to utilise the templates to complement their research notes with a digital capture of research methods including pictorial artefacts of the research methods and outcomes including photographs of equipment (such as pipettes), experimental designs (microtitre plate layouts) and results (cell fluorescent labelling images) as seen in Fig. 17.8. Whilst there was no substitute for good research notation, in developing scientists it was excellent to support these research practices.

There were also examples of students personalising the templates to reflect the nature of individual reflections helping to provide visual connection and association with experiences.

Interestingly, for some students the reflections provided an opportunity to truly consider the importance of being prepared for a day in the laboratory, being able to verbally articulate what they were currently working on and recognising the need to keep far more fastidious notes. Also, the demonstrated recognition is that failure equates to learning as opposed to an indicator of unsuitability for the profession. It is hoped that these early insights will also help rapidly mature their ways of doing science practice which can only be beneficial in the long term. The following quotes (from student's workbooks) demonstrate verbal communication and record keeping.

Example of effective verbal communication skill development from in a student's workbook:

> From listening to the individuals in the group talk about their research I learnt a lot about PD as a disease which is definitely helpful when I am collecting and evaluating information for my literature review. I found it really interesting to gain an insight into how research is conducted and all the different angles of PD that are being researched. I also had to talk to the group about my own project which I found challenging as I hadn't really started to do much reading and I had trouble putting into words what I wanted to achieve. However, in the second meeting I felt much more confident to explain my progress to the group and definitely found it much less challenging.
>
> The main skills and knowledge that I developed from this experience was an improvement in my communication skills and confidence. As well as gaining knowledge in different research methods and technology applications from listening to the others talk about their work and overcoming issues that they were facing with their research.
>
> In the future I will definitely feel much more comfortable talking in front of a group and explaining my ideas. This skill is definitely something that I need to develop further as it is really important to be able to communicate my ideas to other people.

Example of record keeping from a student's workbook:

> I have also learned about good laboratory practice. I have learned through failure that in my case, when working with many new techniques and multiple phases of an experiment at once, that I require much more meticulous note-taking and method recording.

17.4.2 Alignment to Best Practice Approach

This program design incorporates multiple examples of best practice approaches to BL strategies recommended by McGee and Reis (2012) whilst being mindful of Mezirow (2000), Kirschner and van Merrienböer (2008) steps for complex learning and instructional design. In addition, it upholds the key elements advocated for optimal UREs (Auchincloss et al., 2014; Brew, 2013; Brownell & Kloser, 2015; Linn et al., 2015).

17.4.3 Design Process

When designing for learning, be mindful to have a carefully considered initial design process, and to ensure that the process is iterative in nature for subsequent offerings of the course. The design should incorporate the key blueprint components of the four-component instructional design (4C-ID) process (Kirschner & Van Merrienboer, 2008) and the ten steps to complex learning in course/program design, which when combined may lead to transformational learning outcomes for students. Key to these is process-driven, product-orientated or project-orientated activities. In this design, the blended component is focused on the project-orientated approach with cumulative development through step-by-step activities that provide feedback over time. The research component sat very much in the process-driven circle, focusing practice on review of experimental literature and methodologies, including written reflection. Thus, a combination of best practice approaches was included.

The design should apply the keep it simple and straightforward (KISS) principle and provide authentic practices that are aligned with key objectives including discipline expectations such as TLOs (Jones & Yates, 2011; Overton & Johnson, 2016), the Research Skills Development Framework (National Academies of Sciences, 2017; Willison, 2012; Willison & O'Regan, 2007), university expectations (BL strategic priorities) and best practice of BL design (Bath & Bourke, 2010). The design of tasks should be flexible and holistic whilst enabling the demonstration of the visible thinking of research processes. It would be preferable that the tasks incorporated provided connection to prior knowledge and experiences whilst concurrently feeding forward into future activities and are reviewed iteratively in combination with user feedback after each offering.

Furthermore, the provision of sufficient time, appropriate training and financial support assist in enabling well-considered design. The soliciting of feedback and support from professional colleagues regarding the design was important (Gregory & Lodge, 2015). This was a collaborative, iterative process between three academic staff with course responsibilities, for one of whom the courses are core to their degree program, and the learning support team comprised of educational designers, BL experts, a curriculum consultant and an employability consultant.

17.4.4 Pedagogical Strategies

Fundamental to the design of successful blended strategies is critical evaluation of planned activities to ensure that appropriate pedagogical strategies are applied. Design decisions for implementing tools like the PebblePad platform should be grounded in twenty-first-century pedagogical principles, incorporating aspects of personalisation, participation and productivity (Scott, 2015).

Personalisation through assessment was flexible enough to suit the broad variety of project works students undertook. Personalisation also included constructive feedback to feedforward for reflective writing.

The inclusion of BL activities required active participation through the articulation of critical reflection and forward-focussing context. These should ultimately be founded on clear beneficial student learning outcomes, and not merely the addition of an attractive, but potentially distracting or poorly implemented, technology for technology's sake. The inclusion of active learning strategies also supported student engagement and stimulated students to explore and articulate their awareness of their knowledge constructs and the gaps therein as advocated by McGee and Reis (2012).

Productivity included several different strategies—initially, the clear setting of expectations of how to use the blended resources. These included a face-to-face question session and a series of instructional management activities ("how-to" guides) for effectively setting up, submitting and marking assessment. These strategies thereby include supportive guidance and procedural instruction for tasks (Kirschner & Van Merrienboer, 2008). They are "…of the utmost importance so that learners understand how the course works, and whether or not they are equipped to be successful" (McGee & Reis, 2012, p. 16).

17.4.5 Student Readiness

The university where this program was developed had recently introduced the PebblePad platform across the institution in alignment with both university strategic and academic agendas. Thus, significant efforts focused on the successful implementation of the platform in an educational context (Adekola et al., 2017). As recommended (Gregory & Lodge, 2015; Oakley, 2016), these included the allocation of time, funding and specialised BL support teams to implement activities. In the context of the courses discussed in this chapter, students undertaking these courses had already had exposure to the platform and a scaffolded introduction to using it within the year prior to undertaking the first of three courses (Tang & Chaw, 2013). Thus, combined there was institutional and faculty readiness to incorporate new BL opportunities and student readiness for extension and alternate application of the technology was appropriate.

17.4.6 Classroom and Online Technology Utilisation

Based on these experiences, it is recommended that when incorporating BL technology into teaching practices that (i) the technology be sufficiently simple for both students and academic staff to easily engage with and (ii) the skills require be developed progressively. The workbooks developed for this project provide further developmental scaffolded processes for students already familiar with the technology from their first year. Staff were also provided training and support for familiarisation and application (Gregory & Lodge, 2015). Together, these were important elements for setting expectations and minimising potential cognitive overload associated with inquiry-based learning (Kirschner et al., 2006; Overton & Johnson, 2016) in blended formats. They also simplified the type of artefacts collected and incorporate strategies like automatic tagging of these for future curation. The type of technology is also mobile both literally (there being an app for use in the field) and metaphorically (as students can take artefacts created and use them postgraduation and outside of university assessment regimes). Thus, simplicity provides opportunity to use information collated here in multiple ways in the future promoting media stickiness (McGee & Reis, 2012).

Furthermore, the importance of determining additional benefits that can be gained by utilising a platform such as PebblePad is worth mentioning. These benefits should be not only for students but also for administrators and subsequent viewers both for assessment and application in the broader community.

17.4.7 Assessment Strategies

Both project and presentation formats form part of recommendations in the BL approach described. Scientific project development and outcomes were assessed using traditional science methodology (such as reports, poster and oral presentations). In a BL course, it is important to include some assessment submitted in a BL format, which the designers here addressed. In conjunction with traditional assessment, evaluation of experiential learning, connectivity to real-world outcomes and artefacts that form not only part of presentations but are also useful for future applications assessed within the PebblePad platform were implemented. The BL strategy developed active learning activities that subsequently formed part of the assessment regarding student capability to critically construct knowledge over time. The assessment strategies used across this program also included marking rubrics embedded within the online recording platform, thus communicating expectations of completed BL tasks within the same space. Together, these strategies embrace the recommendation to have assessment aligned with activities independent of the level or location of the activity.

17.4.8 Course Implementation

A combination of blended design, setting expectations and processes has been identified as being a key to successful student outcomes in BL. The inclusion of a face-to-face initial consultation with students will ideally remove potential uptake barriers. Setting expectations and process with articulated syllabus maps at the beginning of semester is vital. Here, successful implementation used progressively less detailed templates and exemplars, expectations of time spent on activities, self-check tools both for time-on-task and task completion in the earlier courses. All these strategies support effective principles for implementation and have been discussed for each course within this chapter.

In addition, during implementation, the provision of regular and specific feedback for online activities has also been identified as an important element of BL design and implementation. The application of PebblePad enables rapid and regular individual feedback, provided course sizes are not too large and appropriate marking allocation is attributed. The future use of comment banks for feedback may also prove helpful in managing academic workload with regard to this provision.

There is a general indication that students produce their best work when encouraged to be independent learners. The provision of appropriate developmental scaffolds supports this autonomy and can still provide flexibility for creativity.

17.5 Recommendations and Future Research Directions

In recommending the implementation of a successful blended strategy for undergraduate research experiences, it would be beneficial to ensure alignment with the six recommended categories for best practice in BL (McGee & Reis, 2012) whilst addressing the key challenges identified by (Alammary et al., 2014; Boelens et al., 2017). This project design demonstrates the various benefits associated with such an approach when applied to UREs (Brownell & Kloser, 2015; Linn et al., 2015). It also reinforced the recommendations by Gregory and Lodge (2015) that allocated workload time along with various support mechanisms both technical and financial is important for successful implementation of BL initiatives.

In the future, there exists the opportunity to embed many of the elements discussed in this chapter to any research-based learning activity. The PebblePad platform provides an excellent opportunity to collect and curate scientific reflections and then to utilise these as future evidence or for demonstrating to emerging scientists the ways thinking develops in science.

17.6 Conclusion

This chapter has discussed the design and implementation of a BL strategy that can be applied to course design for undergraduate research experiences regardless of traditional or blended modalities. It also cautions that the incorporation of blended elements should only be considered where they provide enhancement to existing strategies or augment the efficacy of learning outcomes and should adhere to the best practice approaches for twenty-first-century learning, BL design and active learning strategies.

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